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SITE-SPECIFIC TECHNICAL REPORT FOR FREE PRODUCT RECOVERY TESTING AT THE 290 FUEL YARD AND THE NORTH TANKS AREA, TINKER AFB, OKLAHOMA

DRAFT

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
(AFCEE/ERT)
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SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE PRODUCT RECOVERY TESTING AT THE 290 FUEL YARD AND NORTH TANKS AREA, TINKER AFB, OKLAHOMA

by

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for

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28 May 1997

Battelle
505 King Avenue
Columbus, Ohio 43201-2693

Contract No. F41624-94-C-8012

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EXECUTIVE SUMMARY

This report summarizes the field activities conducted at Tinker AFB, for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Tinker AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The tests at Tinker AFB are two of over 40 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Tinker AFB were skimmer pumping, bioslurping, and drawdown pumping.

Bioslurper pilot test activities were conducted at two sites at Tinker AFB: the 290 Fuel Yard and the North Tanks Area. Results from the two test sites are presented separately in the following sections.

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At the 290 Fuel Yard, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well MW-MF-12. The LNAPL recovery testing was conducted in the following sequence: approximately 24 hours in the skimmer configuration, 92.3 hours in the bioslurper configuration, an additional 24 hours in the skimmer configuration, and 4 hours in the drawdown configuration. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

At the North Tanks Area, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well NTA-10a. The LNAPL recovery testing was conducted in the following sequence: 48.1 hours in the skimmer configuration, 74.1 hours in the bioslurper configuration (there were two shutdown periods), an additional 23 hours in the skimmer configuration, and 44.1 hours in the drawdown configuration. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

290 Fuel Yard

A baildown recovery test was conducted at monitoring well MW-MF-12. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and LNAPL recovery potential. Overall the baildown recovery test indicated a relatively rapid rate of LNAPL recovery into the well, with the LNAPL thickness recovering to approximately 50% of initial levels by the end of the 2.5-hour test period. Pilot testing was initiated in this well to determine if vacuum-enhanced conditions would facilitate free product recovery.

A series of pump tests were conducted at monitoring well MW-MF-12: skimmer pumping (before and after bioslurping), bioslurping, and drawdown pumping. Skimmer pump testing initially was conducted in a continuous extraction mode for approximately 24 hours. No significant free-phase LNAPL was recovered during skimmer pump testing, indicating that gravity-driven recovery is minimal. Bioslurper testing was conducted for approximately four days resulting in relatively high recovery in comparison to skimmer pumping. During the first day of pumping, no free product could be recovered; however, by day 2, the free product recovery rate was 24 gallons/day, decreasing to 7.7 gallons/day by day 4. There was no significant LNAPL recovery during the second skimmer pump test although groundwater was produced. Drawdown pump testing was conducted to determine

if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 6 inches below the static water table. Large quantities of particulate material were pulled into the system during drawdown, forcing the early discontinuation of the test. The pump test was not operated for a long enough period to properly judge performance. Overall, these results indicate that gravity-driven recovery techniques were not as effective means of free product recovery as vacuum-enhanced recovery.

Groundwater production rates during bioslurping were significantly higher than rates during the skimmer or drawdown pump tests. The average rate was 2,000 gallons/day, which was transferred directly to a pipeline to the Base Industrial Wastewater Treatment Plant.

Bioslurping also promotes mass removal in the form of volatilization and in situ biodegradation via aeration of the vadose zone. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that may occur during the movement of free-phase LNAPL through the extraction network. Assuming a vapor flowrate of 2 scfm and measured vapor concentrations, approximately 79 lb/day of TPH and 0.14 lb/day benzene were emitted to the air during the bioslurper pump test. Thus, mass removal in the vapor phase is fairly low.

In situ biodegradation rates of 28 to 33 mg/kg-day were measured at three different locations. Based on the radius of influence of 38 ft and a hydrocarbon-impacted soil thickness of 15 ft, mass removal rates via biodegradation are on the order of 170 to 200 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be significant. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

The initial soil gas profiles at the site displayed oxygen-deficient, carbon dioxide-rich, high total volatile hydrocarbon vapor conditions in portions of the site initially, although further movement of soil gas further reduced oxygen concentrations, indicating that the initial oxygen measurement may have been elevated due to installation activities. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW-MF-12 to determine if the vadose zone was being oxygenated via the bioslurper action. Oxygen concentrations were impacted at most monitoring points in the vicinity of MW-MF-12. However, oxygen concentrations typically dropped over time, possibly due to pulling contaminated, oxygen-deficient soil-gas past the monitoring points. It is likely that over time these areas would

become oxygenated. In short, a four day extraction time frame at approximately 2 scfm is insufficient to exchange sufficient pore volumes of soil gas to fully oxygenate the zone of influence.

In summary, the on-site testing at the 290 Fuel Yard, Tinker AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Free-phase LNAPL recovery was only sustainable in the bioslurper mode and therefore, bioslurping is recommended at this site provided a cost-effective means for long-term water treatment is viable. The in situ respiration test and vadose zone radius of influence testing demonstrate that bioventing is feasible at this site.

North Tanks Area

A baildown recovery test was conducted at three monitoring wells at the North Tanks Area: NTA-14a, RC-5, and NTA-10a. Although there was some fuel present in monitoring wells NTA-14a and RC-5, there were very large quantities present in monitoring well NTA-10a (10.28 ft initial thickness). Also, recovery was faster in monitoring well NTA-10a than in the other wells. Therefore, monitoring well NTA-10a was selected for the bioslurper pump tests.

A series of pump tests were conducted at monitoring well NTA-10a: skimmer pumping (before and after bioslurping), bioslurping, and drawdown pumping. Skimmer pump testing was conducted in a continuous extraction mode for approximately 47 hours. LNAPL recovery during skimmer pumping was significant with a total of 45 gallons of LNAPL was recovered during this test, with an average recovery rate of 22 gallons/day. LNAPL recovery rates were higher during the bioslurper pump test than during the skimmer pump test. A total of 170 gallons of LNAPL were extracted during the bioslurper pump test, with daily average recovery rates of 55 gallons/day. These results demonstrate that operation of the bioslurper system in the bioslurper mode was an effective means of free-product recovery. LNAPL recovery dropped during the second skimmer pump test compared to the initial skimmer pump test. Totals of 10 gallons of LNAPL were recovered, with a daily average recovery rate of 10 gallons/day. These results indicate that free-product recovery may not be sustainable. Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 1 ft below the static water table. LNAPL recovery was significant with a recovery rate of 43 gallons/day initially. The recovery rate did drop to 22 gallons/day by the second day of testing. Groundwater production was significant, with a total of 2,054.2 gallons produced. These results demonstrate that operation of the bioslurper system in the drawdown mode was effective, but may not be sustainable.

Groundwater production rates during bioslurping were significantly higher than rates during the skimmer or drawdown pump tests. The average rate was 2,200 gallons/day, with a total recovery of 6,795 gallons. Contaminant concentrations in groundwater were low and groundwater was able to be discharged to the Base Industrial Wastewater Treatment Plant.

Bioslurping also promotes mass removal in the form of volatilization and in situ biodegradation via aeration of the vadose zone. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that may occur during the movement of free-phase LNAPL through the extraction network. Given, the measured vapor flowrate and vapor concentrations, initial hydrocarbon removal rates were approximately 21 lb/day of TPH and 0.023 lb/day of benzene. Thus, mass removal in the vapor phase is not significant.

In summary, the on-site testing at the North Tanks Area, Tinker AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL free product recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Liquid-phase recovery was possible in all extraction modes, although slightly higher in the bioslurper mode than during skimmer or drawdown pumping. However, groundwater production during bioslurping was significant and could pose a logistical problem for the Base. Skimmer pumping appeared to be effective at free-product recovery, while generation 10% of the groundwater produced during bioslurping. Therefore, skimmer pumping is probably a better option for free-product recovery at this site.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE PRODUCT RECOVERY TESTING
AT THE 290 FUEL YARD AND THE NORTH TANKS AREA,
TINKER AFB, OKLAHOMA

28 May 1997

1.0 INTRODUCTION

This report describes activities performed and data collected during field tests at Tinker Air Force Base (AFB), Arkansas, to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at Tinker AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The tests at Tinker AFB are two of over 40 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the Test Plan and Technical Protocol for Bioslurping (Battelle, 1995). Test provisions specific to activities at Tinker AFB were described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping

technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at Tinker AFB were skimmer pumping, bioslurping, and drawdown pumping. The specific test objectives, methods, and results for the Tinker AFB test program are discussed in the following sections.

1.2 Testing Approach

Bioslurper pilot test activities were conducted at two sites at Tinker AFB: the 290 Fuel Yard and the North Tanks Area. Results from the two test sites are presented separately in the following sections.

Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At the 290 Fuel Yard, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well MW-MF-12. The LNAPL recovery testing was conducted in the following sequence: approximately 24 hours in the skimmer configuration, 92.3 hours in the bioslurper configuration, an additional 24 hours in the skimmer configuration, and 4 hours in the drawdown configuration. Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

At the North Tanks Area, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted at monitoring well NTA-10a. The LNAPL recovery testing was conducted in the following sequence: 48.1 hours in the skimmer configuration, 74.1 hours in the bioslurper configuration (there were two shutdown periods), an additional 23 hours in the skimmer configuration, and 44.1 hours in the drawdown configuration. Measurements of extracted soil gas

composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

2.0 FREE PRODUCT RECOVERY TESTING AT THE 290 FUEL YARD

2.1 Site Description

Tinker AFB is located southeast of Oklahoma City in central Oklahoma and occupies 4,541 acres. It is bound to the north and west by residential, industrial, and commercial land uses and to the south and east by agricultural land uses.

The Petroleum, Oil, and Lubricants (POL) Yard was operative from 1942 to 1986 and recovery operations were begun in June of 1987 as an interim action. Figure 1 shows the layout of the 290 Fuel Yard and the monitoring well network. The original system consisted of 4 pumps which recovered product from monitoring wells MF-24 and MF-26. Average fuel recovery was approximately 10 gallons/week. The system underwent modifications in 1988, after which time an auto-skimmer was used and extraction took place only from monitoring well MF-24. Average fuel recovery following these modifications was approximately 17 gallons/week. During the operational period from June 1987 to December 1988, a total of 1,450 gallons of fuel and 190,000 gallons of water were removed (U.S. Army Corps of Engineers, 1989). An Expedited Response Action (ERA) report estimated 50,000 gallons of free product at the site; however, this calculation was based on apparent product thicknesses. The amount should be revised to 12,500 gallons to reflect actual thicknesses (U.S. Army Corps of Engineers, 1989).

Previous investigations indicate that contamination is only in the perched aquifer and that the regional aquifer seems to remain unaffected. Groundwater flow in the regional aquifer is generally to the southwest. Monitoring wells where free product has recently been measured include MF-12 and 2-46B. Respective thicknesses of 1.2 ft and 0.4 ft were found at these wells in October 1996.

2.2 Pilot Test Methods

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at the 290 Fuel Yard.

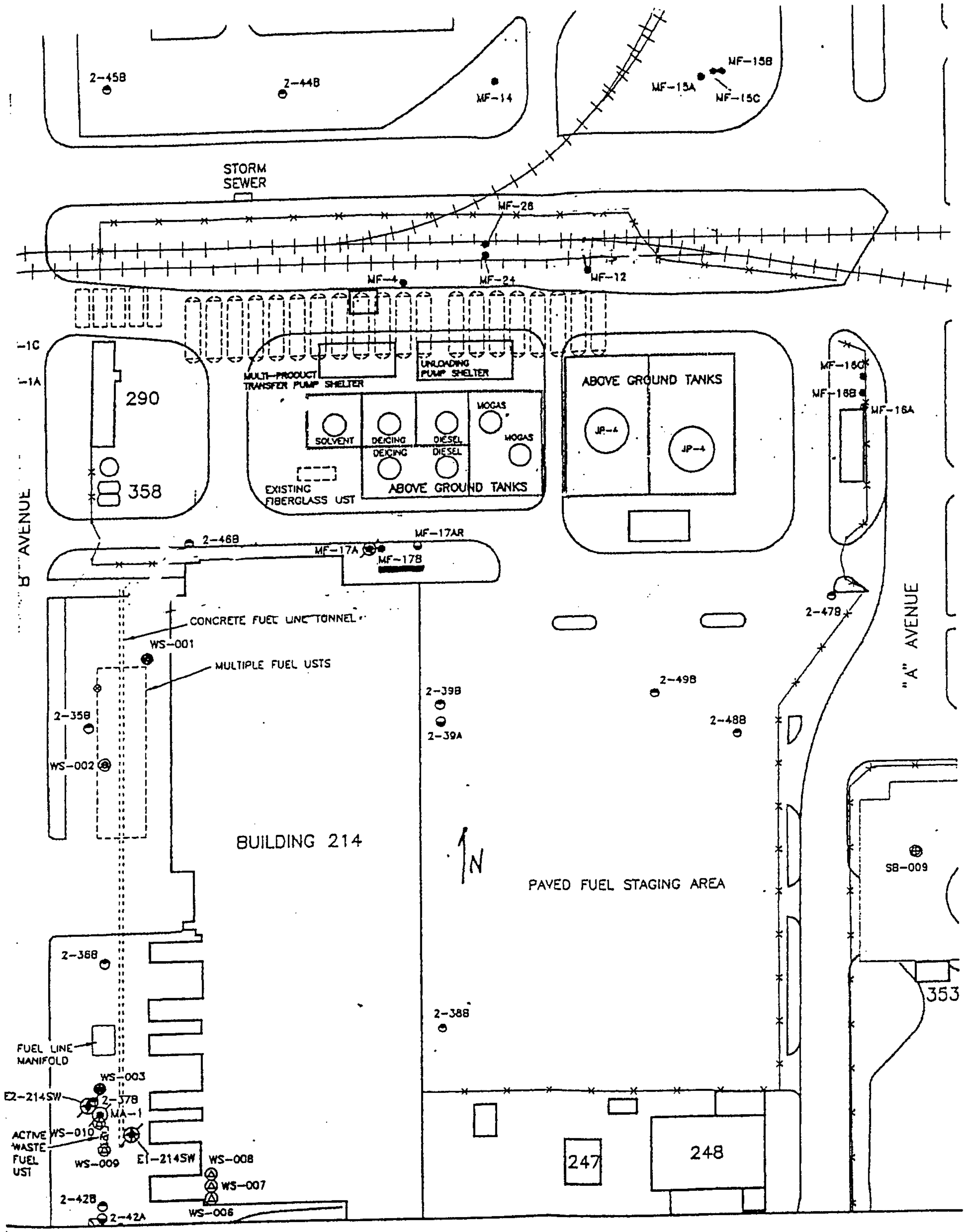

Figure 1. Site Diagram and Monitoring Well Locations at the 290 Fuel Yard

2.2.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring well MW-MF-12 was evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon® bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 2.5 hours.

2.2.2 Well Construction Details

A short-term bioslurper pump test was conducted at existing monitoring well MW-MF-12. The well is constructed of 2-inch-diameter, schedule 40 polyvinyl chloride (PVC). The monitoring well was installed to a total depth of 20 ft with 10 ft of screen. The casing stickup is 3.7 ft. A schematic diagram showing general construction details and location of the monitoring well is shown in Figure 2.

2.2.3 Soil Gas Monitoring Point Installation

Three monitoring points were installed in the area of monitoring well MW-MF-12 and were labeled MPA, MPB, and MPC. The locations and construction details of the monitoring points are illustrated in Figure 2.

The monitoring points consisted of sets of ¼-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at the appropriate depths, and the annular space corresponding to the screened length was filled with silica sand. The interval between the screened lengths was filled with bentonite clay chips, as was the space from the top of the shallowest screened length to the ground surface. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal. Monitoring point MPA was installed to a depth of 8.0 ft into a 6-inch diameter borehole and was screened to three depths: 2.5 to 3.0, 4.5 to 5.0 ft, and 7.5 to 8.0 ft. Monitoring points MPB and MPC were installed to a depth of 7.0 ft into a 6-inch diameter borehole and were screened to three depths: 2.5 to 3.0, 4.5 to 5.0 ft, and 6.5 to 7.0 ft. A Type K thermocouple was installed with the screened interval at MPA-8.0′ and MPB-3.0′.

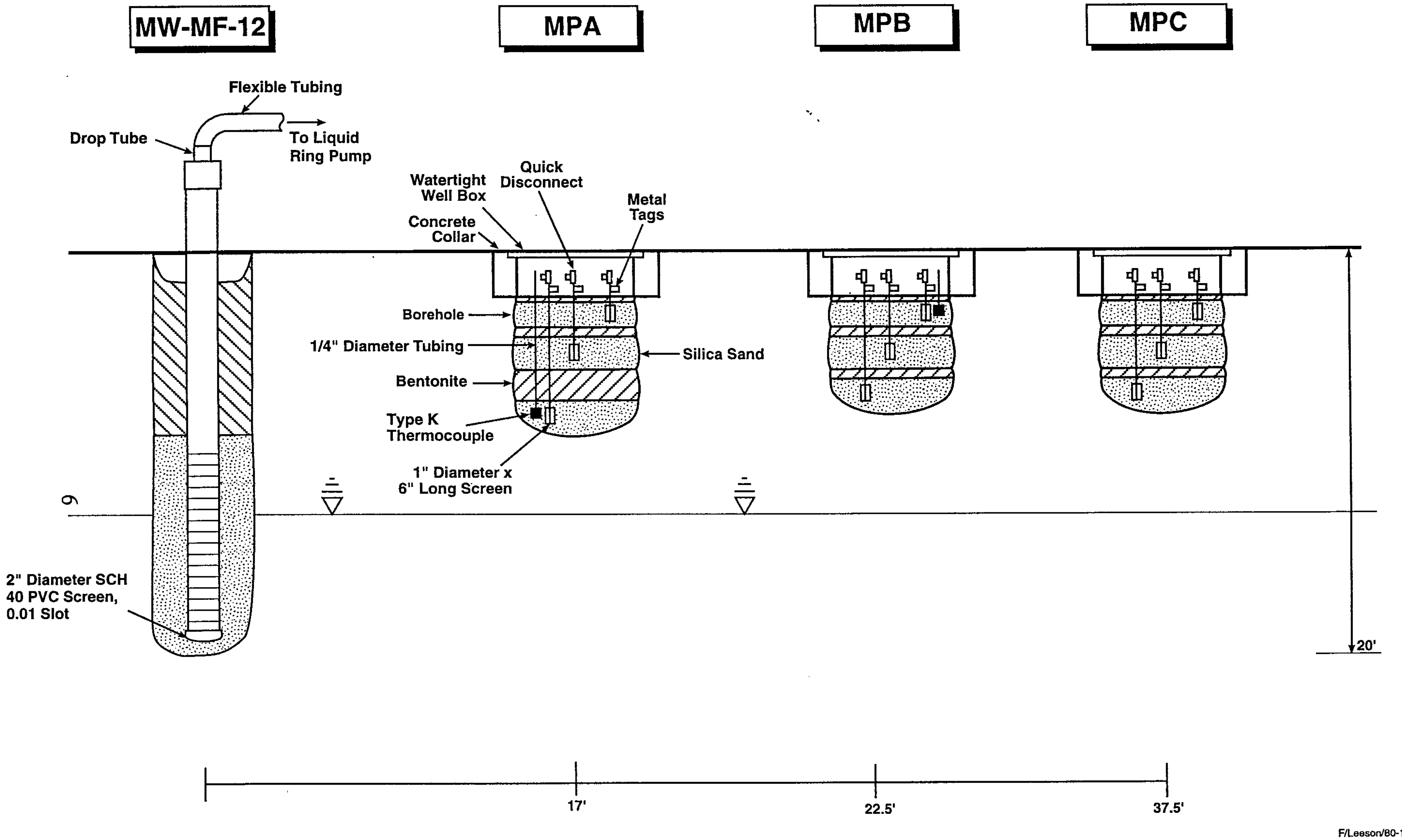

Figure 2. Schematic Diagram Showing Construction Details of Monitoring Well MW-MF-12 and Soil Gas Monitoring Points at the 290 Fuel Yard

After installation of the monitoring points, initial soil gas measurements were taken with a GasTechtor portable O_2/CO_2 meter and a GasTech Trace-Techtor portable hydrocarbon meter. Oxygen levels were depressed at monitoring point MPB only, although TPH concentrations were elevated at several locations (Table 1). These results indicate that contamination may not be uniform in this area.

2.2.4 Soil Sampling and Analysis

Four soil samples were collected during the installation of monitoring points MPA and MPC and were labeled T2-MPA-7-7.5, T2-MPA-7.5-8.0, T2-MPC-5-5.5, and T2-MPC-6.25-6.75. The soil samples were collected in a brass sleeve using a split-spoon sampler. The samples were placed in an insulated cooler, chain-of-custody records and shipping papers were completed, and the samples were sent to Alpha Analytical, Inc., in Sparks, Nevada. Samples T2-MPA-7-7.5 and T2-MPC-6.25-6.75 were analyzed for benzene, toluene, ethylbenzene, and total xylenes (BTEX) and TPH. Samples T2-MPA-7.5-8.0 and T2-MPC-5-5.5 were analyzed for bulk density, particle size, and porosity. The laboratory analytical reports are provided in Appendix B.

2.2.5 LNAPL Recovery Testing

2.2.5.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), oil/water separator, and required support equipment are carried to the test location on a trailer. The trailer was located near monitoring well MW-MF-12, the well cap was removed, a coupling and tee were attached to the top of the well, and the drop tube was lowered into the well. The drop tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted groundwater was treated by passing the effluent through an oil/water separator to a 325 gallon tank and then pumped to a connection to the Base Industrial Wastewater Treatment Plant.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All

Table 1. Initial Soil Gas Compositions at the 290 Fuel Yard

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)
MPA	3.0	20.9	0.75	16
	5.0	14.9	6.9	8,000
	8.0	20.9	0.9	320
MPB	3.0	8.5	6.2	16,000
	5.0	6.9	6.5	20,000
	7.0	6.8	6.5	18,000
MPC	3.0	20	3.5	280
	5.0	17.9	2.0	560
	7.0	17.5	3.1	1,450

site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

2.2.5.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. A peristaltic pump was used to conduct the skimmer pump test. The tube was held in place at the oil/water interface and the peristaltic pump was started at 1002, 15 January 1997, to begin the skimmer pump test. The test was operated continuously for approximately 24 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

An LNAPL sample was collected during the skimmer pump test and was labeled T2-LNAPL. The sample was sent to Alpha Analytical, Inc., Sparks, Nevada for analysis of BTEX, 1,2,4-trimethylbenzene, 1,2,5-trimethylbenzene, and C-range compounds. The laboratory analytical report is provided in Appendix B.

2.2.5.3 Bioslurper Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface. The PVC connecting tee was removed, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 3). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 1153, 16 January 1997, to begin the bioslurper pump test. The test was initiated approximately 2 hours after the skimmer pump test and was operated continuously for 92.3 hours. The pump head vacuum was approximately 25″Hg and the well head vacuum was approximately 20.5″H_2O. The vapor flowrate was so low that it did not register on the pitot tube. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

2.2.5.4 Second Skimmer Pump Test

Upon completion of the bioslurper pump test, preparations were made to begin the second skimmer pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The liquid ring pump was used to conduct the skimmer pump test (Figure 4). The drop tube was held in place at the oil/water interface and the liquid ring pump was started at 0855, 20 January 1997, to begin the second skimmer pump test. The test was initiated approximately 0.75 hour after the bioslurper pump test and was operated continuously for approximately 24 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

2.2.5.5 Drawdown Pump Test

Upon completion of the second skimmer pump test, preparations were made to begin the drawdown pump test. Prior to test initiation, depths to LNAPL and groundwater were measured.

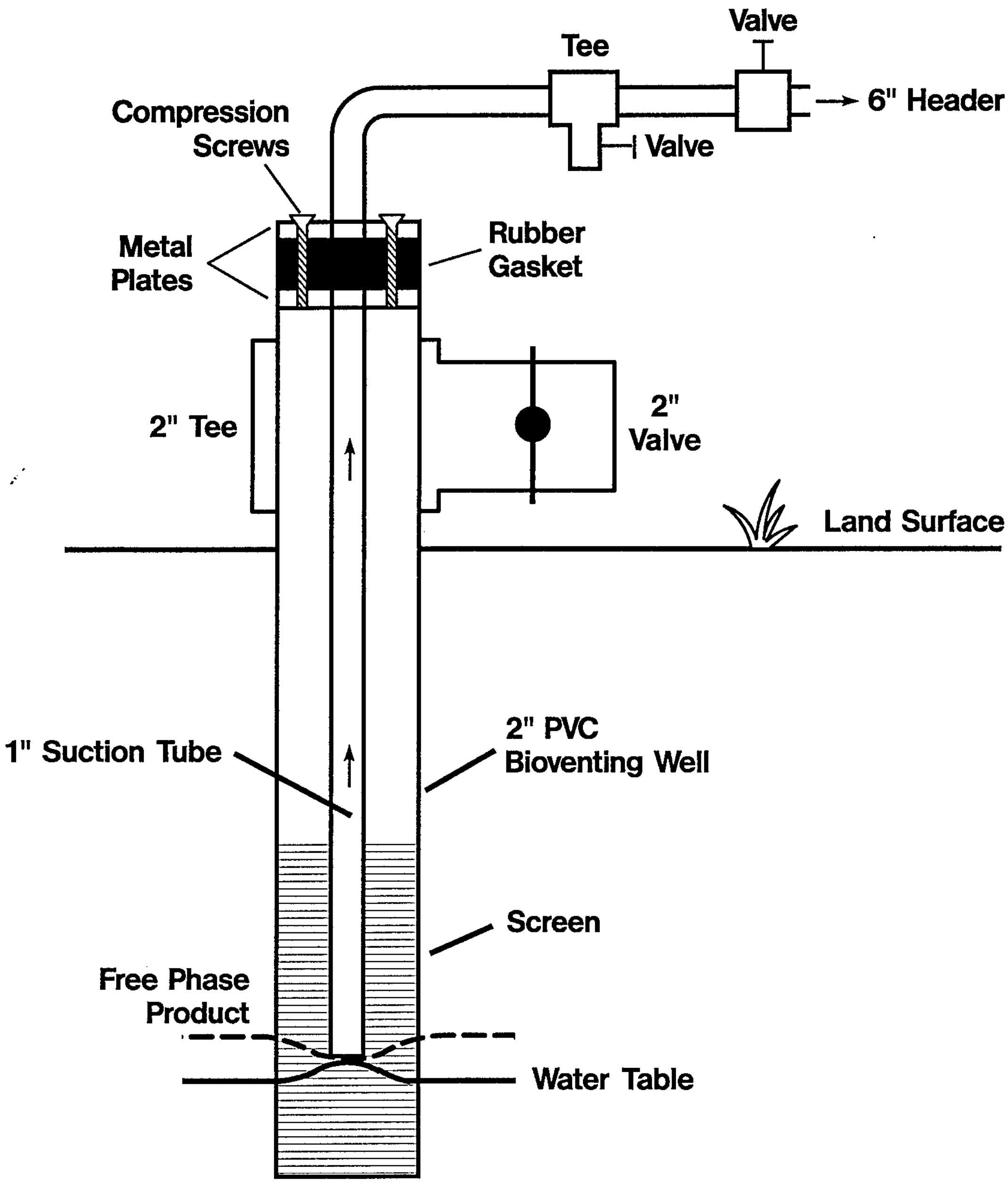

Figure 3. Drop Tube Placement and Valve Position for the Bioslurper Pump Test

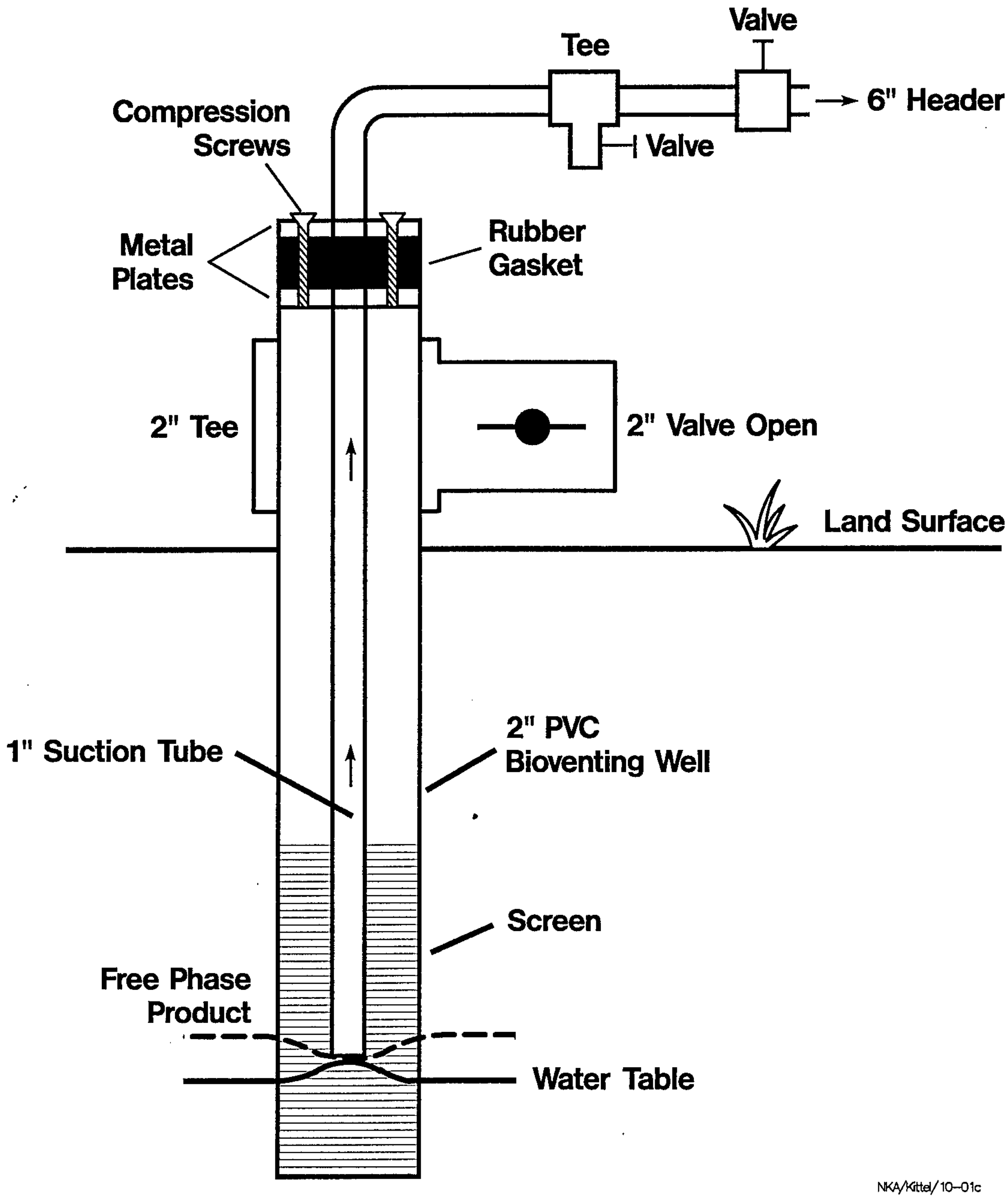

Figure 4. Drop Tube Placement and Valve Position During the Skimmer Pump Test

The slurper tube was then set so that the tip was approximately 6 inches below the oil/water interface with the PVC connecting tee open to the atmosphere (Figure 5). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 0927, 21 January 1997, to begin the drawdown pump test. The test was initiated approximately 2 hours after the second skimmer pump test and was operated continuously for approximately 4 hours. An excessive amount of particulate material was pulled into the pump during the drawdown pump test, forcing an early shutdown. The pump head vacuum was approximately 6″Hg and the vapor flowrate was approximately 9.9 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

2.2.5.6 Off-Gas Sampling and Analysis

Two soil gas samples were collected from the off-gas during the pump tests. The samples were collected in a Tedlar® bag, transferred to Summa® canisters, and were labeled Tinker-MF-12-1 and Tinker-MF-12-2. Sample Tinker-MF-12-1 was collected during the bioslurper pump test after approximately 48 hours after initiation of bioslurping. Sample Tinker-MF-12-2 was collected during the second skimmer pump test after approximately 5 hours after initiation of skimmer pumping. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

2.2.5.7 Groundwater Sampling and Analysis

Two groundwater samples were collected during the pump tests. The samples were collected from the oil/water separator and were labeled Tinker-MF-12-1 and Tinker-MF-12-2. Sample Tinker-MF-12-1 was collected during the bioslurper pump test after approximately 48 hours after initiation of bioslurping. Sample Tinker-MF-12-2 was collected during the second skimmer pump test after approximately 5 hours after initiation of skimmer pumping. The samples were collected in 40-mL VOA vials containing HCl preservative. The samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH.

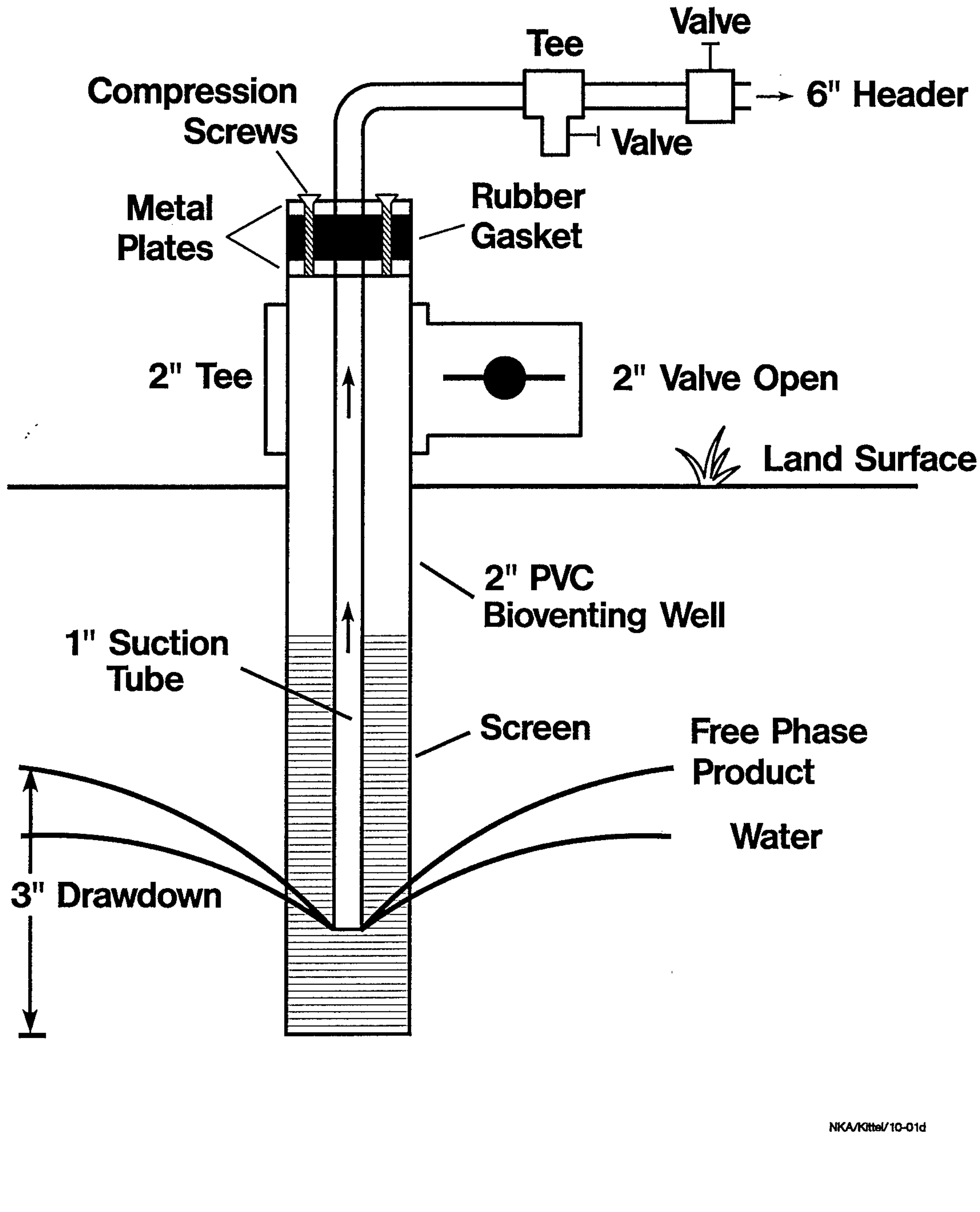

Figure 5. Drop Tube Placement and Valve position for the Drawdown Pump Test

2.2.6 Bioventing Analyses

2.2.6.1 Soil Gas Permeability Testing

Soil gas permeability test data were collected during the bioslurper pump test in monitoring well MW-MF-12. Before a vacuum was established in the extraction well, the initial soil gas pressures at the monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well which was the starting point for the soil gas permeability testing. Soil gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil gas pressure data were collected frequently during the first 20 minutes of the test. The soil gas pressures were recorded throughout the bioslurper pump test to determine the bioventing radius of influence. Test data are provided in Appendix E.

2.2.6.2 In Situ Respiration Testing

Air containing approximately 2% helium was injected into three monitoring points for approximately 24 hours beginning on 20 January 1997. The setup for the in situ respiration test is described in the Test Plan and Technical Protocol a Field Treatability Test for Bioventing (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through the following monitoring points at the depths indicated: MPA-5.0′, MPB-7.0′, and MPC-7.0′. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The in situ respiration test was terminated on 22 January 1997. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix F.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate

of helium diffusion. As a general rule, we have found that if helium concentrations at test completion are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

2.3 Pilot Test Results

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at the 290 Fuel Yard.

2.3.1 Baildown Test Results

Results from the baildown test in monitoring well MW-MF-12 are presented in Table 2. A total volume of approximately 0.67 L (0.18 gallons) was removed by hand bailing from monitoring well MW-MF-12. The LNAPL recovery rate was relatively rapid, with the LNAPL thickness recovering to approximately 50% of initial levels by the end of the 2.5-hour test period. Pilot testing was initiated in this well to determine if vacuum-enhanced conditions would facilitate free product recovery.

2.3.2 Soil Sample Analyses

Table 3 shows the BTEX and TPH concentrations measured in the soil samples collected from the 290 Fuel Yard. BTEX and TPH concentrations were low, with an average TPH concentration of 98 mg/kg. All BTEX compounds were below detection limits. The results of the physical characterization of the soil are presented in Table 4.

2.3.3 LNAPL Pump Test Results

2.3.3.1 Initial Skimmer Pump Test Results

No significant quantities of LNAPL or groundwater were recovered during this test during 24 hours of continuous pumping (Table 5). Figure 6 illustrates the fuel recovery versus time during each

Table 2. Results of Baildown Testing at Monitoring Well MW-MF-12, 290 Fuel Yard

Sample Collection Date	Time (min)	Depth to Groundwater (ft)[1]	Depth to LNAPL (ft)[1]	LNAPL Thickness (ft)
Initial Reading 1/3/97	0	12.93	11.85	1.08
1/3/97	1	13.80	--	0
1/3/97	2	13.05	--	0
1/1/97	3	12.70	--	0
1/3/97	4	12.42	--	0
1/3/97	5	12.19	12.18	0.01
1/3/97	10	12.08	12.06	0.02
1/3/97	15	11.97	11.94	0.03
1/3/97	30	11.93	11.85	0.08
1/3/97	60	11.90	11.79	0.11
1/3/97	90	11.87	11.76	0.11
1/3/97	120	12.12	11.72	0.40
1/3/97	150	12.29	11.69	0.60

[1] Depth from top of casing, which was 3 ft above ground level.

Table 3. TPH and BTEX Concentrations in Soil Samples from the 290 Fuel Yard

Parameter	Concentration (mg/kg)	
	T2-MPA-7-7.5	T2-MPC-6.25-6.75
TPH (purgeable)	190	<10
Benzene	<0.020	<0.020
Toluene	<0.020	<0.020
Ethylbenzene	<0.020	<0.020
Total Xylenes	<0.020	<0.020

Table 4. Physical Characterization of Soils from the 290 Fuel Yard

Parameter		Sample	
		T2-MPA-7.5-8.0	T2-MPC-5-5.5
Density (g/cm^3)		1.27	1.13
Particle Size	Sand	49	80.2
	Silt	29	10.3
	Clay	22	9.5
Porosity (%)		52.1	57.4

Table 5. Pump Test Results at Monitoring Well MW-MF-12, 290 Fuel Yard

Time (days)	Recovery Rate (gallons/day)							
	Skimmer Pump Test		Bioslurper Pump Test		Second Skimmer Pump Test		Drawdown Pump Test[1]	
	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater
1	0	0	0	1,400	0	920	0	0
2	NA	NA	24	2,200	NA	NA	NA	NA
3	NA	NA	12	2,000	NA	NA	NA	NA
4	NA	NA	7.7	2,700	NA	NA	NA	NA
Average	0	0	8.9	2,000	0	920	0	0
Total Recovery (gal)	0	0	34.1	7775.5	0	426.1	0	0

NA = Not applicable.

1 The drawdown pump test was only conducted for approximately four hours. In the drawdown configuration, so much sand was pulled with the groundwater that the system was becoming plugged with sand in a very short time; therefore, the test could not be conducted.

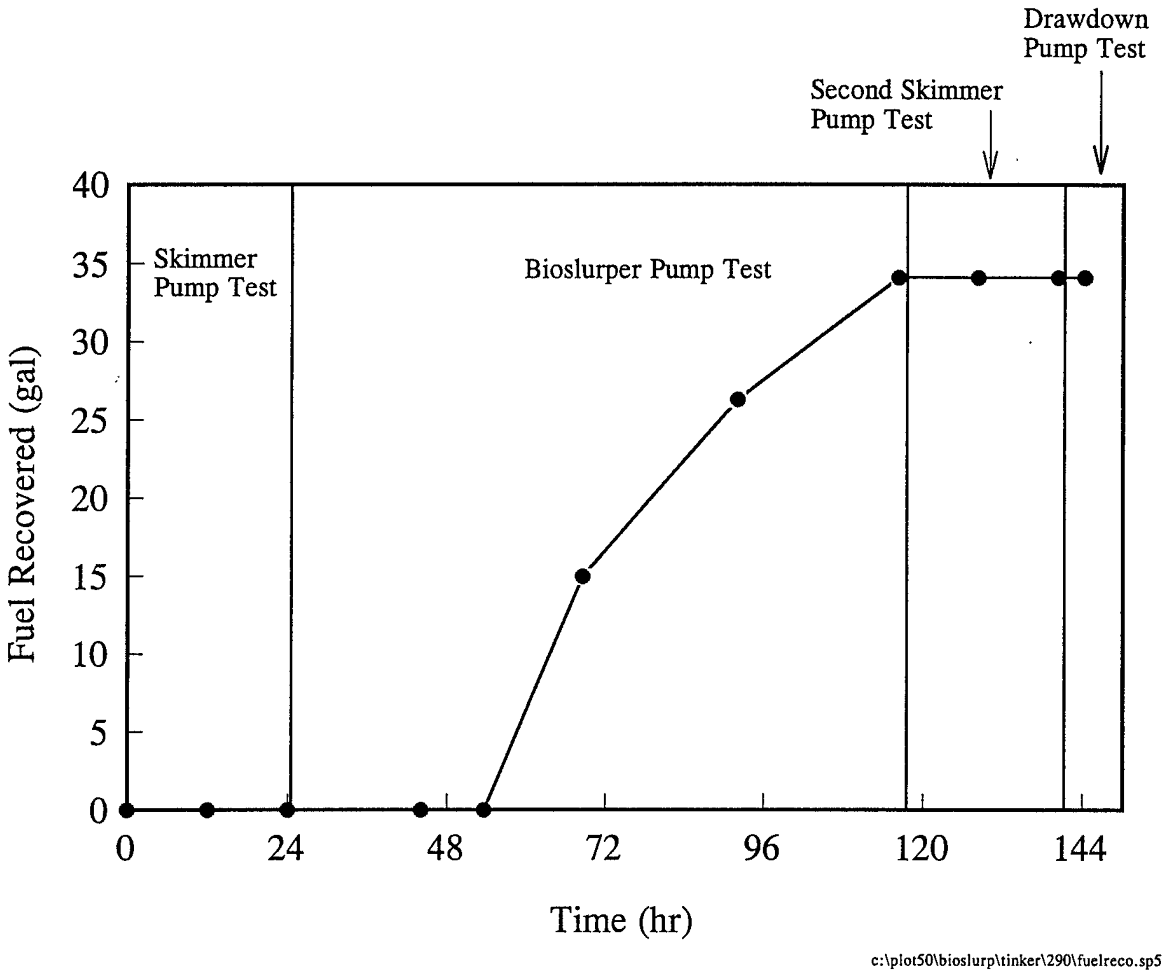

Figure 6. Fuel Recovery Versus Time During Each Pump Test at the 290 Fuel Yard

pump test. These results indicate that gravity-driven recovery techniques are not feasible for free-product recovery.

2.3.3.2 Bioslurper Pump Test Results

LNAPL recovery rates increased significantly during the bioslurper pump test as compared to the skimmer pump test. A total of 34.1 gallons of LNAPL and 7,777.5 gallons of groundwater were extracted during the bioslurper pump test (Table 5). During the first day of pumping, no free product could be recovered; however, by day 2, the free product recovery rate was 24 gallons/day, decreasing to 7.7 gallons/day by day 4. Figure 7 presents the fuel recovery rate versus time during the bioslurper pump test.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations were impacted at most monitoring points in the vicinity of MW-MF-12 (Table 6). However, oxygen concentrations typically dropped over time, possibly due to pulling contaminated, oxygen-deficient soil-gas past the monitoring points. It is likely that over time these areas would become oxygenated.

2.3.3.3 Second Skimmer Pump Test

No significant fuel was recovered during the second skimmer pump test, although, in contrast to the initial skimmer pump test, a total of 426.1 gallons of groundwater were produced (Table 5). These results demonstrate that operation of the bioslurper system in the skimmer mode was not an effective means of free-product recovery.

2.3.3.4 Drawdown Pump Test

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 6 inches below the static water table. Unfortunately, large quantities of particulate material were pulled into the system during drawdown, forcing the early discontinuation of the test. The pump test was not operated for a long enough period to properly judge performance.

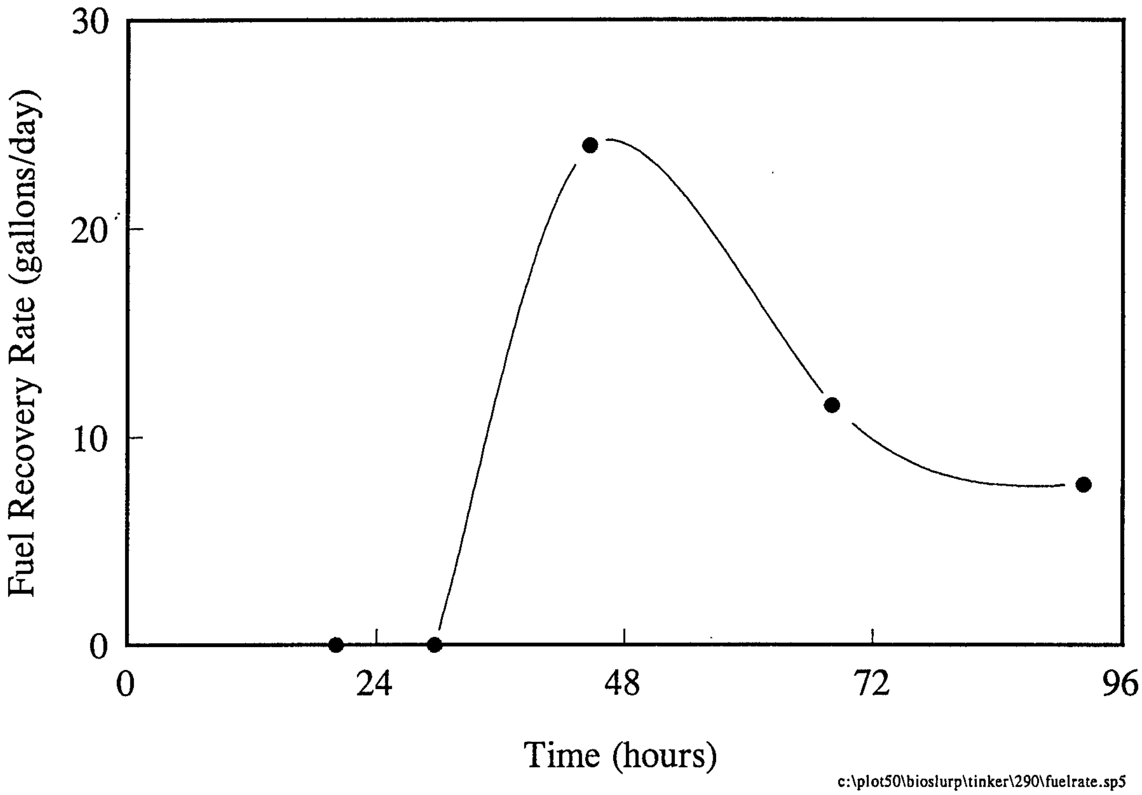

Figure 7. **Fuel Recovery Rate Versus Time During the Bioslurper Pump Test at the 290 Fuel Yard**

Table 6. In Situ Oxygen Concentrations During the Bioslurper Pump Test at Monitoring Well MW-MF-12, 290 Fuel Yard

Monitoring Point	Oxygen Concentrations (%) Versus Time (hours)				
	0	4.5	21	44.5	68
MPA-3.0	20.9	20.5	20.5	14	21
MPA-5.0	14.9	10	3.5	2.9	4.0
MPA-8.0	20.9	20	F	F	F
MPB-3.0	8.5	8.4	8.5	21	2.75
MPB-5.0	6.9	13	7.5	12	0
MPB-7.0	6.8	12.5	4.9	0.5	0.25
MPC-3.0	20	19.9	20	20.1	15.5
MPC-5.0	17.9	15	9.2	7.0	4.0
MPC-7.0	17.5	13.5	F	7.0	3.25

F = Frozen. Monitoring point could not be sampled due to water freezing in line.

2.3.3.5 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Contaminant concentrations in groundwater were relatively low, with average TPH concentrations of 25 mg/L and average total BTEX concentrations of 5.8 mg/L (Table 7). These values typically meet discharge requirements.

Off-gas samples from the bioslurper system also were collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 8. Off-gas concentrations were relatively high; however, the vapor flowrate was so low that it did not register on the pitot. If a vapor flowrate of 2 scfm is assumed and using a concentration of 67,500 ppmv TPH and 245 ppmv benzene, approximately 79 lb/day of TPH and 0.14 lb/day benzene were emitted to the air during the bioslurper pump test. The composition of LNAPL in terms of BTEX, trimethylbenzenes, and C-range compounds is shown in Tables 9 and 10. The C-range fractionation is also shown in Figure 8.

Table 7. BTEX and TPH Concentrations in Extracted Groundwater During the Bioslurper Pump Test at the 290 Fuel Yard

Parameter	Concentration (mg/L)	
	Tinker-MF-12-1	Tinker-MF-12-2
TPH (purgeable)	23	27
Benzene	1.4	2.1
Toluene	0.89	0.48
Ethylbenzene	0.61	0.58
Total Xylenes	2.9	2.7

Table 8. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at the 290 Fuel Yard

Parameter	Concentration (mg/L)	
	Tinker-MF-12-1	Tinker-MF-12-2
TPH referenced to jet fuel	66,000	69,000
C2 - C4 Hydrocarbons	6,000	2,400
Benzene	270	220
Toluene	140	<5.3
Ethylbenzene	96	100
Total Xylenes	300	280

Table 9. BTEX Concentrations in LNAPL at the 290 Fuel Yard

Compound	Concentration (mg/kg)
Benzene	<530
Toluene	<530
Ethylbenzene	<530
Total Xylenes	9,200
1,2,5-Trimethylbenzene	4,700
1,2,4-Trimethylbenzene	5,500

Table 10. C-Range Compounds in LNAPL from the 290 Fuel Yard

C-Range Compound	Percentage of Total
<C8	26.18
C9	16.39
C10	16.86
C11	12.07
C12	12.26
C13	8.43
C14	4.87
C15	1.72
C16	0.60
C17	0.63

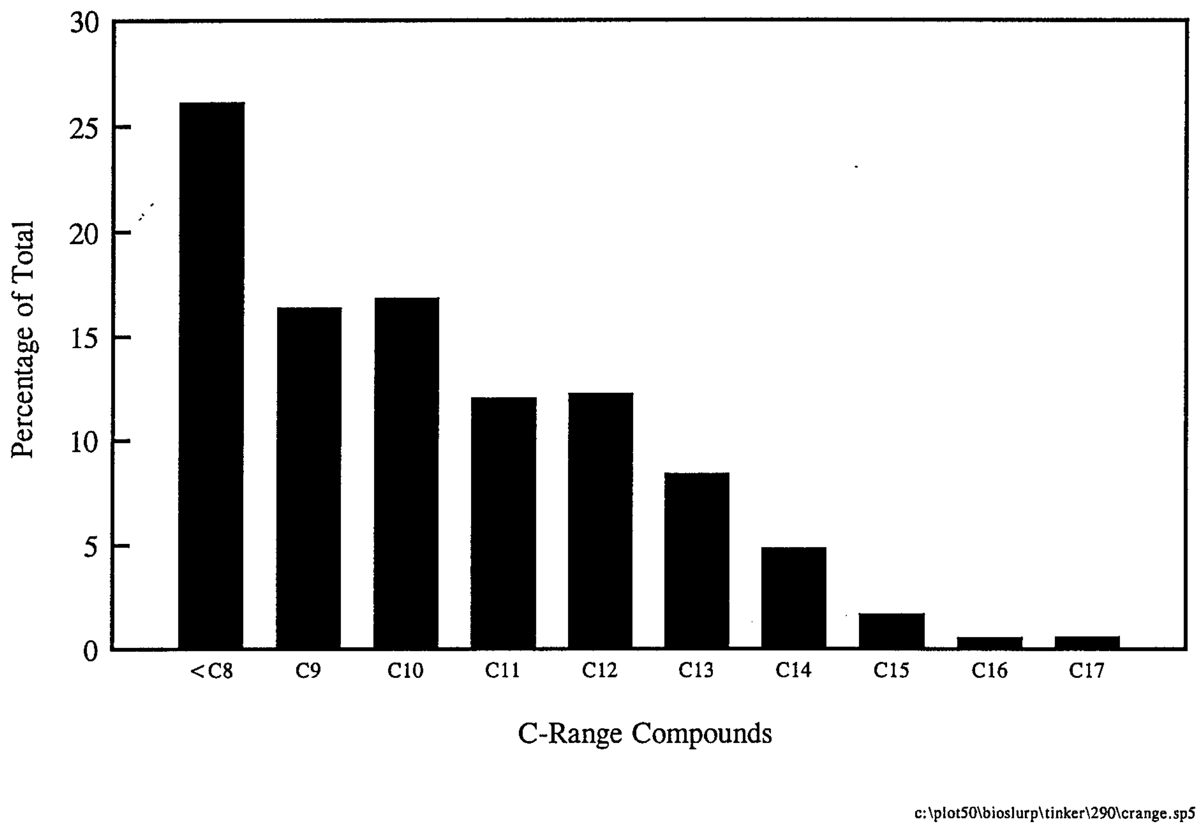

Figure 8. C-Range Compounds in LNAPL from the 290 Fuel Yard

2.3.4 Bioventing Analyses

2.3.4.1 Soil Gas Permeability and Radius of Influence

The radius of influence is calculated by plotting the log of the pressure change at a specific monitoring point versus the distance from the extraction well. The radius of influence is then defined as the distance from the extraction well where 0.1 inch of H_2O can be measured. No significant pressure change could be detected during the bioslurper pump test; however, based on changes in oxygen levels, it appears that a radius of influence of at least 37.5 ft (distance of furthest monitoring point) is possible.

2.3.4.2 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 11. Oxygen depletion was relatively fast, with oxygen utilization rates ranging from 1.7 to 2.0 $\%O_2$/hr. Biodegradation rates ranged from 28 to 33 mg/kg-day.

Table 11. In Situ Respiration Test Results at the 290 Fuel Yard

Monitoring Point	Oxygen Utilization Rate (%/hr)	Biodegradation Rate (mg/kg-day)
MPA-5.0	1.7	28
MPB-7.0	2.0	33
MPC-7.0	1.8	29

2.4 Discussion

A baildown recovery test was conducted at monitoring well MW-MF-12. Baildown recovery tests provide a qualitative indication of the presence of mobile, free-phase LNAPL and LNAPL recovery potential. Overall the baildown recovery test indicated a relatively rapid rate of LNAPL recovery into the well, with the LNAPL thickness recovering to approximately 50% of initial levels

by the end of the 2.5-hour test period. Pilot testing was initiated in this well to determine if vacuum-enhanced conditions would facilitate free product recovery.

A series of pump tests were conducted at monitoring well MW-MF-12: skimmer pumping (before and after bioslurping), bioslurping, and drawdown pumping. Skimmer pump testing initially was conducted in a continuous extraction mode for approximately 24 hours. No significant free-phase LNAPL was recovered during skimmer pump testing, indicating that gravity-driven recovery is minimal. Bioslurper testing was conducted for approximately four days resulting in relatively high recovery in comparison to skimmer pumping. During the first day of pumping, no free product could be recovered; however, by day 2, the free product recovery rate was 24 gallons/day, decreasing to 7.7 gallons/day by day 4. There was no significant LNAPL recovery during the second skimmer pump test although groundwater was produced. Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 6 inches below the static water table. Large quantities of particulate material were pulled into the system during drawdown, forcing the early discontinuation of the test. The pump test was not operated for a long enough period to properly judge performance. Overall, these results indicate that gravity-driven recovery techniques were not as effective means of free product recovery as vacuum-enhanced recovery.

Groundwater production rates during bioslurping were significantly higher than rates during the skimmer or drawdown pump tests. The average rate was 2,000 gallons/day, which was transferred directly to a pipeline to the Base Industrial Wastewater Treatment Plant.

Bioslurping also promotes mass removal in the form of volatilization and in situ biodegradation via aeration of the vadose zone. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that may occur during the movement of free-phase LNAPL through the extraction network. Assuming a vapor flowrate of 2 scfm and measured vapor concentrations, approximately 79 lb/day of TPH and 0.14 lb/day benzene were emitted to the air during the bioslurper pump test. Thus, mass removal in the vapor phase is fairly low.

In situ biodegradation rates of 28 to 33 mg/kg-day were measured at three different locations. Based on the radius of influence of 38 ft and a hydrocarbon-impacted soil thickness of 15 ft, mass removal rates via biodegradation are on the order of 170 to 200 lbs of hydrocarbon per day. Thus, mass removal rates via biodegradation could be significant. These results indicate that bioventing is feasible at this site. Air injection bioventing is preferable over bioslurping and soil vapor extraction with respect to the elimination of hydrocarbon vapor emissions.

The initial soil gas profiles at the site displayed oxygen-deficient, carbon dioxide-rich, high total volatile hydrocarbon vapor conditions in portions of the site initially, although further movement of soil gas further reduced oxygen concentrations, indicating that the initial oxygen measurement may have been elevated due to installation activities. These conditions indicate that natural biodegradation of residual petroleum hydrocarbons has occurred, but is limited by oxygen availability. Soil gas concentrations were measured during the bioslurper test at monitoring points adjacent to monitoring well MW-MF-12 to determine if the vadose zone was being oxygenated via the bioslurper action. Oxygen concentrations were impacted at most monitoring points in the vicinity of MW-MF-12. However, oxygen concentrations typically dropped over time, possibly due to pulling contaminated, oxygen-deficient soil-gas past the monitoring points. It is likely that over time these areas would become oxygenated. In short, a four day extraction time frame at approximately 2 scfm is insufficient to exchange sufficient pore volumes of soil gas to fully oxygenate the zone of influence.

In summary, the on-site testing at the 290 Fuel Yard, Tinker AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Free-phase LNAPL recovery was only sustainable in the bioslurper mode and therefore, bioslurping is recommended at this site provided a cost-effective means for long-term water treatment is viable. The in situ respiration test and vadose zone radius of influence testing demonstrate that bioventing is feasible at this site.

3.0 FREE PRODUCT RECOVERY TESTING AT THE NORTH TANKS AREA

3.1 Site Description

The North Tank Area, operative since 1943, is located north of Building 3001 and is used as an informal staging area. Building 3001 was placed on the National Priorities List (NPL) in 1987, and the North Tanks Area has been designated as an operable unit of the Building 3001 site.

Five underground storage tanks (USTs) have at one time stored various liquid fuels at the North Tanks Area; however, four USTs have since been removed leaving only one remaining active tank. Tank 3401 is a 20,000-gallon diesel tank installed in 1972 to replace a previously existing tank and is still operative. USTs which have been removed from the site include Tank 3403, Tank 3404, and Tank 3405, which were used to contain waste oil, No. 2 fuel oil, and gasoline respectively. An

unnumbered sump tank was also removed from the site. Slow chronic leaks were known to exist in Tanks 3404 and 3405. Other primary contaminants at the site include trichloroethane (TCE) and chromium resulting from solvents and liquid wastes from Building 3001.

The uppermost stratigraphic unit underlying the North Tanks Area is a low-permeability surficial clay unit ranging from 6 to 10 ft in thickness. Below the surficial clay unit is a 5- to 11-ft upper sandy layer consisting primarily of silty sand to poorly graded sand. An upper shale unit consisting of weathered shale and siltstone underlies the upper sand unit and is found at thicknesses of 3 to 11 ft. The next underlying unit is described as fine- to medium-grained cross-bedded sandstone and is referred to as the lower sandstone layer. A lower shale unit which extends laterally across the entire North Tanks Area underlies the 7- to 16-ft thick lower sandstone unit. These five stratigraphic units represent a vertical depth of approximately 40 ft and correspond with hydrogeologic formations underlying the North Tanks Area. The upper shale layer acts as an upper confining layer, therefore resulting in an upper perched aquifer corresponding to the upper sand unit. Similarly, the lower shale unit serves as a lower confining layer, resulting in a lower perched aquifer which corresponds to the lower sandstone unit. Groundwater flow in the upper perched aquifer is primarily to the south and in the lower perched aquifer to the northwest and west. Locations and screened intervals of existing wells are detailed in Figure 9.

Soil analysis data reveals that total petroleum hydrocarbons as diesel (TPH-D) is found at greatest concentrations in the lower perched aquifer. A maximum TPH-D concentration of 130,000 mg/kg is found at NTA-10A and NTA-10B and decreases to the south and west with concentrations of approximately 10,000 mg/kg found at NTA-7A and NTA-7B. Concentrations are seen to decrease rapidly outside of the free-product zone. BTEX contamination in soil also tends to be highest in the lower perched aquifer and is most pronounced in the soil near Tank 3404. High concentrations of total xylenes, ethylbenzene, toluene, and benzene are 18,000 μg/kg, 10,000 μg/kg, 4,000 μg/kg, and 500 μg/kg respectively.

Groundwater data indicates TPH-D concentrations in the upper perched aquifer to be less than 0.5 mg/L and concentrations in the lower perched aquifer to be 10 mg/L in the free-product zone. Groundwater BTEX concentrations in the upper perched aquifer were generally below detection limits. The lower aquifer tends to have elevated benzene, ethylbenzene, and xylene concentrations in the vicinity of Tank 3401 and 3404 and elevated toluene concentrations near Tank 3401 and NTA-4A. Chlorinated ethene solvents are found at highest concentrations to the northwest of the North Tanks Area in both the upper and lower aquifers, with the most pronounced levels

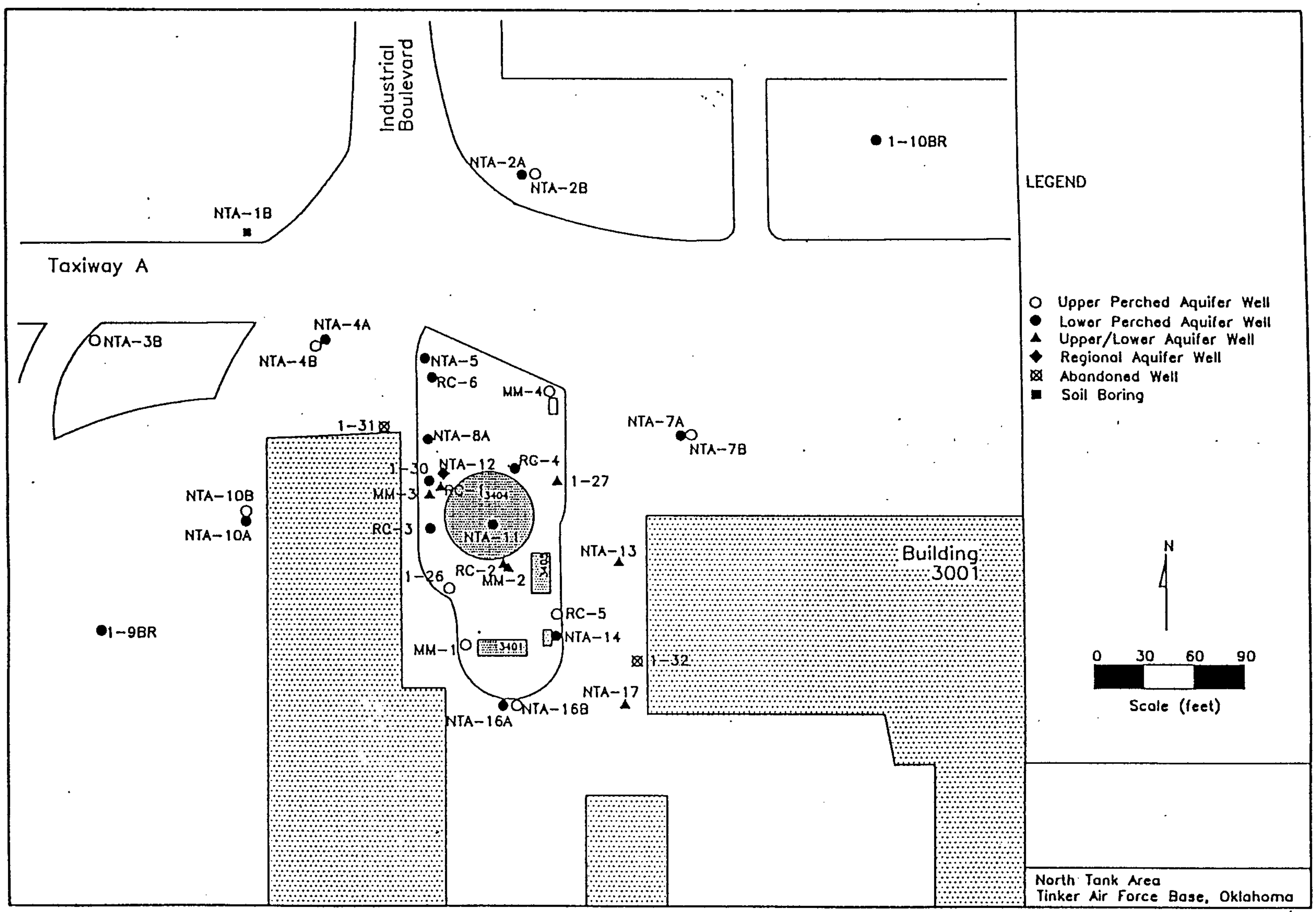

Figure 9. Location of Monitoring Wells at the North Tanks Area

being found near NTA-4. Detected solvents include trichloroethene (TCE), tetrachloroethene (PCE), vinyl chloride, and cis-1,2- dichloroethene.

Free product has been observed in a 50,000 ft^2 area of the North Tanks Area and tends to be greater in the lower than in the upper perched aquifer. Free-product thicknesses tend to be greatest immediately north of Tank 3404 and at the western boundary of the free-product area near NTA-10A. Wells with greater than 10 ft of apparent free product include NTA-8A, NTA-10A, NTA-11, 1-30, and RC-4. Product thickness measurements for individual wells can be found in Appendix A. Although various recovery operations have been in place since 1991, the primary pumping wells since 1994 have been RC-4, NTA-11, NTA-8, 1-30, and RC-3 which are all completed in the lower formation. One product-only pump has been operating almost constantly at RC-4, and another has been alternated between NTA-8 and NTA-11. The average daily production of product since 1994 has been 8 to 9 gallons per day (gpd). Free product is encountered at depths of 13 to 17 ft below ground surface (bgs) in the upper perched aquifer; however, free product is primarily recovered from wells screened at deeper intervals to recover free product which has been trapped beneath the upper shale layer.

3.2 Pilot Test Methods

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at the North Tanks Area. No monitoring wells were installed at this site, because the monitoring well that was selected was located between a building and a road, making the installation of monitoring points impractical. Therefore, no soil samples were collected at this site.

3.2.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring wells NTA-14a, RC-5, and NTA-10a were evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon® bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 24 hours at monitoring wells NTA-14a and RC-5 and for approximately 15 hours at monitoring well NTA-10a.

3.2.2 Well Construction Details

A short-term bioslurper pump test was conducted at existing monitoring well NTA-10a. The well is constructed of 4-inch-diameter, stainless steel. The well was installed to a depth of 33 ft with 10 ft of screen.

3.2.3 LNAPL Recovery Testing

3.2.3.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), oil/water separator, and required support equipment are carried to the test location on a trailer. The trailer was located near monitoring well NTA-10a, the well cap was removed, a coupling and tee were attached to the top of the well, and the slurper tube was lowered into the well. The slurper tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted groundwater was treated by passing the effluent through a filter box, oil/water separator, then to a 325 gallon tank and then pumped into a 6,200 gallon storage tank which was periodically drained and the groundwater transported to the Industrial Wastewater Treatment Plant.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

3.2.3.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. A peristaltic pump was used to conduct the skimmer pump test. The tube was held in place at the oil/water interface and the peristaltic pump was started 1050, 23 January 1997, to begin the skimmer pump test. The test was operated continuously for 48.1 hours. The LNAPL and groundwater extraction

rates were monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

3.2.3.3 Bioslurper Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The drop tube was then set at the LNAPL/groundwater interface. The PVC connecting tee was removed, sealing the wellhead and allowing the pump to establish a vacuum in the well. A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 1120, 25 January 1997, to begin the bioslurper pump test. The test was initiated approximately 0.5 hr after the skimmer pump test and was operated for 74.1 hours with two shutdown periods. The pump head vacuum was approximately 23"Hg, the well head vacuum was approximately 13"H_2O, and the vapor flowrate was approximately 9.6 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

An LNAPL sample was collected during the bioslurper pump test and was labeled NTA-10a. The sample was sent to Alpha Analytical, Inc., Sparks, Nevada for analysis of BTEX, TPH,1,2,4-trimethylbenzene, and 1,2,5-trimethylbenzene.

3.2.3.4 Second Skimmer Pump Test

Upon completion of the bioslurper pump test, preparations were made to begin the second skimmer pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The liquid ring pump was used to conduct the skimmer pump test. The drop tube was held in place at the oil/water interface and the liquid ring pump was started at 1247, 30 January 1997, to begin the second skimmer pump test. The test was initiated approximately 2 hours after the bioslurper pump test and was operated continuously for approximately 23 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

3.2.3.5 Drawdown Pump Test

Upon completion of the second skimmer pump test, preparations were made to begin the drawdown pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set so that the tip was approximately 1.0 ft below the oil/water interface with the PVC connecting tee open to the atmosphere. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started at 1305, 31 January 1997, to begin the drawdown pump test. The test was initiated approximately 1.5 hours after the bioslurper pump test and was operated continuously for 45.6 hours. The pump head vacuum was approximately 12″Hg and the vapor flowrate was approximately 36 scfm. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

3.2.3.6 Off-Gas Sampling and Analysis

A soil gas sample was collected from the system off-gas during the bioslurper pump test. The sample was collected in a Tedlar® bag and transferred to a Summa® canister. The sample was labeled Tinker-NTA-10A-1 and was collected approximately 48 hr after test initiation. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

3.2.3.7 Groundwater Sampling and Analysis

One groundwater sample was collected during the bioslurper pump test. The sample was collected from the oil/water separator and was labeled Tinker-NTA-10A-1 and was collected approximately 48 hr after test initiation. The sample was collected in a 40-mL VOA vial containing HCl preservative. The sample was checked to ensure no headspace was present and was then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH.

3.3 Pilot Test Results

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at the North Tanks Area.

3.3.1 Baildown Test Results

Results from the baildown tests are presented in Tables 12 through 14. Although there was some fuel present in monitoring wells NTA-14a and RC-5, there were very large quantities present in monitoring well NTA-10a (10.28 ft initial thickness). Also, recovery was faster in monitoring well NTA-10a than in the other wells. Therefore, monitoring well NTA-10a was selected for the bioslurper pump tests.

3.3.2 LNAPL Pump Test Results

3.3.2.1 Initial Skimmer Pump Test Results

LNAPL recovery during skimmer pumping was significant with a total of 45 gallons of LNAPL was recovered during this test, with an average recovery rate of 22 gallons/day (Table 15). A total of 400 gallons of groundwater was produced with an average production rate of 200 gallons/day (Table 15). Fuel recovery versus time during each pump test is shown in Figure 10. These results indicate that gravity-driven recovery techniques may be feasible at this site.

3.3.2.2 Bioslurper Pump Test Results

LNAPL recovery rates were higher during the bioslurper pump test than during the skimmer pump test (Figure 10). A total of 170 gallons of LNAPL and 6,795 gallons of groundwater were extracted during the bioslurper pump test, with daily average recovery rates of 55 gallons/day for LNAPL and 2,200 gallons/day for groundwater (Table 15). Figure 11 presents the fuel recovery rate versus time during the bioslurper pump test. These results demonstrate that operation of the bioslurper system in the bioslurper mode was an effective means of free-product recovery.

Table 12. Results of Baildown Testing at Monitoring Well NTA-14a, North Tanks Area

Sample Collection Date	Time (min)	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 1/2/97	0	20.39	19.75	0.64
1/2/97	1	21.69	21.52	0.17
1/2/97	2	21.55	21.39	0.16
1/1/97	3	21.45	21.28	0.17
1/2/97	4	21.38	21.19	0.19
1/2/97	5	21.30	21.13	0.17
1/2/97	10	21.13	20.95	0.18
1/2/97	15	20.75	20.57	0.18
1/2/97	30	20.65	20.47	0.18
1/2/97	60	20.59	20.40	0.19
1/2/97	1,080	20.04	19.85	0.19
1/2/97	1,440	20.04	19.83	0.21

Table 13. Results of Baildown Testing at Monitoring Well RC-5, North Tanks Area

Sample Collection Date	Time (min)	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 1/2/97	0	17.83	17.73	0.10
1/2/97	1	19.72	--	0
1/2/97	2	19.61	--	0
1/1/97	3	19.51	--	0
1/2/97	4	19.43	--	0
1/2/97	5	19.35	19.33	0.02
1/2/97	10	19.19	19.13	0.06
1/2/97	15	19.05	18.95	0.10
1/2/97	30	18.97	18.87	0.10
1/2/97	45	18.90	18.78	0.12
1/2/97	60	18.85	18.73	0.12
1/2/97	1,080	17.80	17.73	0.07
1/2/97	1,440	17.82	17.73	0.09

Table 14. Results of Baildown Testing at Monitoring Well NTA-10a, North Tanks Area

Sample Collection Date	Depth to Groundwater (ft)[1]	Depth to LNAPL (ft)	LNAPL Thickness (ft)
Initial Reading 1/17/97-1515	30	19.72	10.28
1/17/97-1609	30	23.60	6.40
1/17/97-1640	30	24.00	6.00
1/1/97-1647	30	23.25	6.75
1/17/97-1651	30	23.00	7.00
1/17/97-1657	30	22.68	7.32
1/17/97-1713	30	22.18	7.82
1/17/97-1718	30	23.09	6.91
1/17/97-1756	27.17	21.67	5.50
1/18/97-0800	29.69	20.78	8.91

[1] Bottom of well was at 30 ft bgl. Depths to groundwater of 30 ft indicate that the entire well was filled with free product. No groundwater could be detected.

Table 15. Pump Test Results at Monitoring Well NTA-10a, North Tanks Area

Time (days)	Recovery Rate (gallons/day)							
	Skimmer Pump Test		Bioslurper Pump Test		Second Skimmer Pump Test		Drawdown Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater
1	25	240	70	2,300	10	830	43	1,500
2	20	160	72	2,400	NA	NA	22	720
3	NA	NA	27	2,200	NA	NA	NA	NA
Average	22	200	55	2,200	10	830	33	1,100
Total Recovery (gal)	45	400	170	6,795	10	800	60	2,054.2

NA = Not applicable

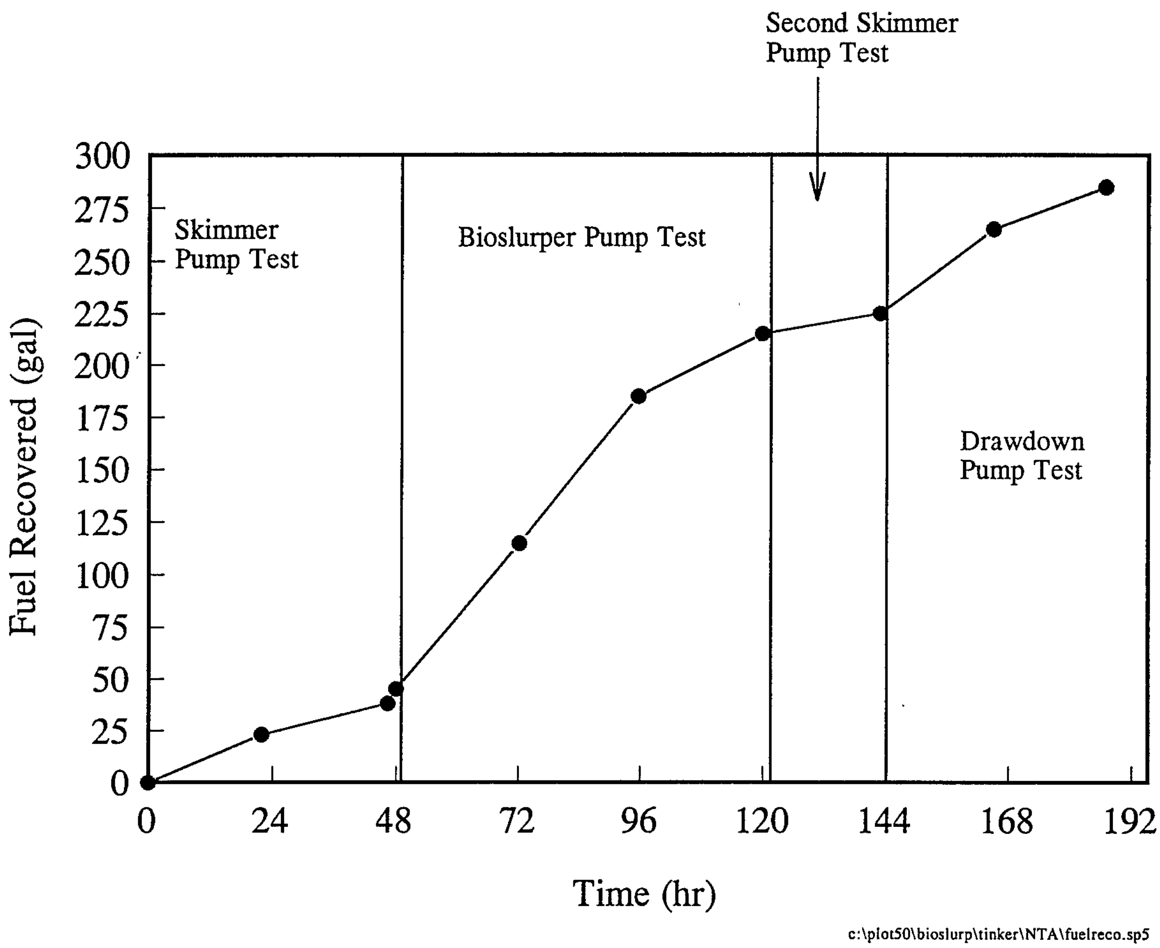

Figure 10. Fuel Recovery Versus Time During Each Pump Test at the North Tanks Area

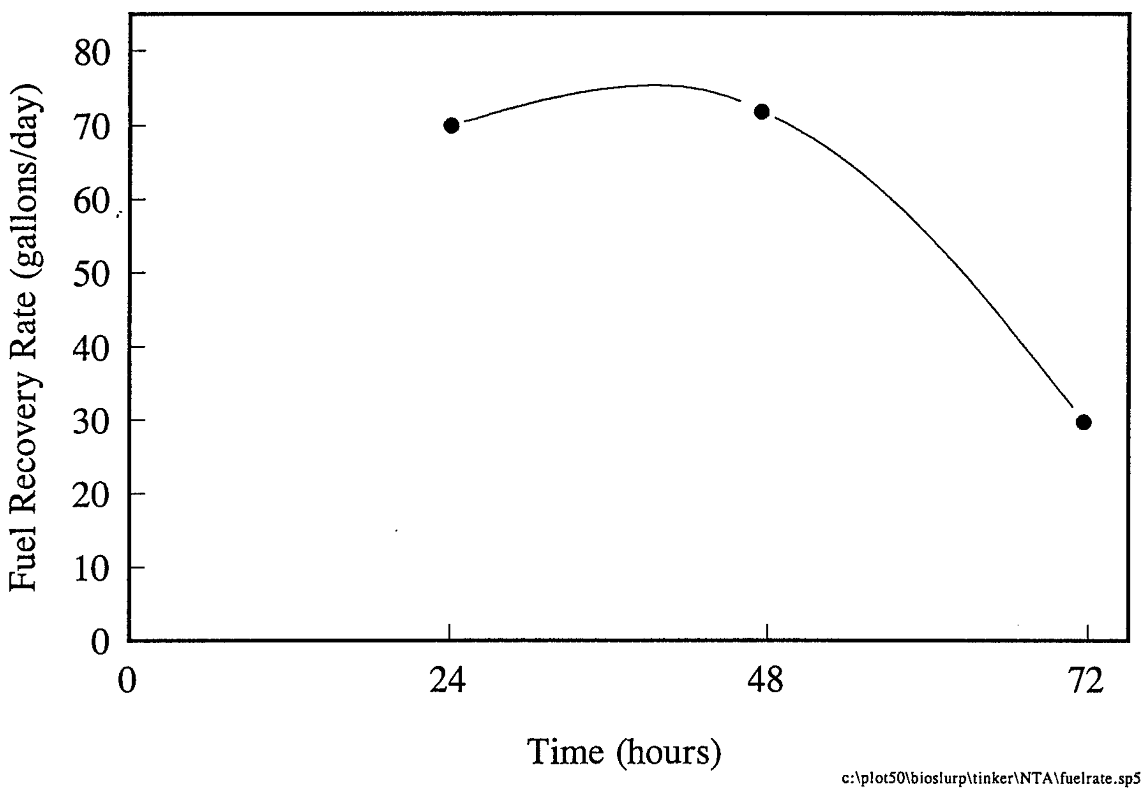

Figure 11. **Fuel Recovery Rate Versus Time During the Bioslurper Pump Test at the North Tanks Area**

3.3.2.3 Second Skimmer Pump Test

LNAPL recovery dropped during the second skimmer pump test compared to the initial skimmer pump test. Totals of 10 gallons of LNAPL and 800 gallons of groundwater were recovered, with daily average recovery rates of 10 gallons/day for LNAPL and 830 gallons/day for groundwater (Table 15). These results indicate that free-product recovery may not be sustainable.

3.3.2.4 Drawdown Pump Test

Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 1 ft below the static water table. LNAPL recovery was significant with a recovery rate of 43 gallons/day initially. The recovery rate did drop to 22 gallons/day by the second day of testing. Groundwater production was significant, with a total of 2,054.2 gallons produced (Table 15). These results demonstrate that operation of the bioslurper system in the drawdown mode was effective, but may not be sustainable.

3.3.2.5 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Contaminant concentrations in groundwater were relatively low, with a TPH concentration of 53 mg/L and a total BTEX concentration of 0.78 mg/L (Table 16). These values typically meet discharge requirements.

An off-gas sample from the bioslurper system also was collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 17. Given a vapor discharge rate of 9.6 scfm and using an average concentration of 3,700 ppmv TPH and 8.2 ppmv benzene, approximately 21 lb/day of TPH and 0.023 lb/day benzene was emitted to the air during the bioslurper pump test. The composition of LNAPL in terms of BTEX and trimethylbenzene concentrations is shown in Tables 18 and 19. The C-range fractionation also is shown in Figure 12.

3.4 Discussion

A baildown recovery test was conducted at three monitoring wells at the North Tanks Area: NTA-14a, RC-5, and NTA-10a. Although there was some fuel present in monitoring wells NTA-14a

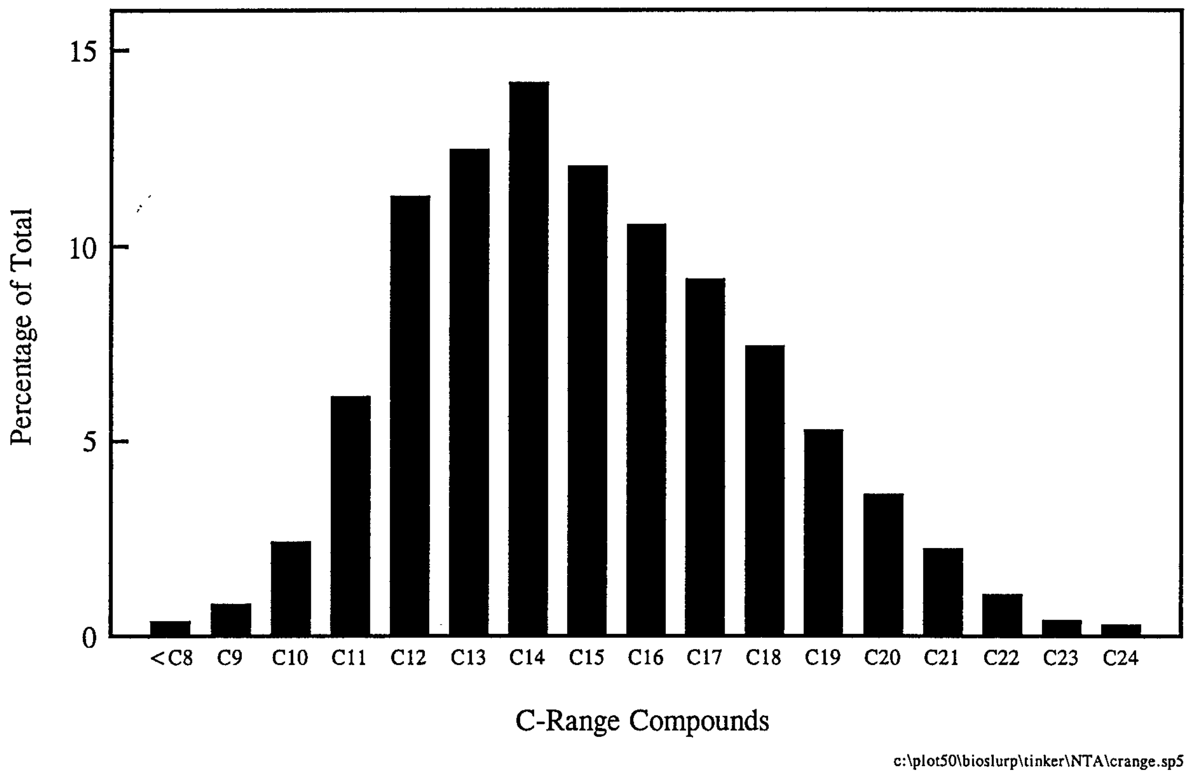

Figure 12. C-Range Compounds in LNAPL from the North Tanks Area

Table 16. **BTEX and TPH Concentrations in Extracted Groundwater During the Bioslurper Pump Test at the North Tanks Area**

Parameter	Concentration (mg/L)
	Tinker-NTA-10A-1
TPH (purgeable)	53
Benzene	<0.050
Toluene	0.082
Ethylbenzene	0.18
Total Xylenes	0.49

Table 17. **BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at the North Tanks Area**

Parameter	Concentration (ppmv)
	Tinker-NTA-10A-1
TPH referenced to JP-4 jet fuel	3,700
C2 - C4 Hydrocarbons	150
Benzene	8.2
Toluene	14
Ethylbenzene	22
Total Xylenes	54

Table 18. BTEX Concentrations in LNAPL at the North Tanks Area

Compound	Concentration (mg/kg)
Benzene	<48
Toluene	<48
Ethylbenzene	<48
Total Xylenes	370
1,2,5-Trimethylbenzene	390
1,2,4-Trimethylbenzene	1,000

Table 19. C-Range Compounds in LNAPL from the North Tanks Area

C-Range Compound	Percentage of Total
<C8	0.40
C9	0.85
C10	2.42
C11	6.16
C12	11.27
C13	12.47
C14	14.18
C15	12.05
C16	10.56
C17	9.19
C18	7.46
C19	5.29
C20	3.63
C21	2.24
C22	1.09
C23	0.43
C24	0.32

and RC-5, there were very large quantities present in monitoring well NTA-10a (10.28 ft initial thickness). Also, recovery was faster in monitoring well NTA-10a than in the other wells. Therefore, monitoring well NTA-10a was selected for the bioslurper pump tests.

A series of pump tests were conducted at monitoring well NTA-10a: skimmer pumping (before and after bioslurping), bioslurping, and drawdown pumping. Skimmer pump testing was conducted in a continuous extraction mode for approximately 47 hours. LNAPL recovery during skimmer pumping was significant with a total of 45 gallons of LNAPL was recovered during this test, with an average recovery rate of 22 gallons/day. LNAPL recovery rates were higher during the

bioslurper pump test than during the skimmer pump test. A total of 170 gallons of LNAPL were extracted during the bioslurper pump test, with daily average recovery rates of 55 gallons/day. These results demonstrate that operation of the bioslurper system in the bioslurper mode was an effective means of free-product recovery. LNAPL recovery dropped during the second skimmer pump test compared to the initial skimmer pump test. Totals of 10 gallons of LNAPL were recovered, with a daily average recovery rate of 10 gallons/day. These results indicate that free-product recovery may not be sustainable. Drawdown pump testing was conducted to determine if a cone of groundwater depression would enhance LNAPL recovery. The water table was depressed approximately 1 ft below the static water table. LNAPL recovery was significant with a recovery rate of 43 gallons/day initially. The recovery rate did drop to 22 gallons/day by the second day of testing. Groundwater production was significant, with a total of 2,054.2 gallons produced. These results demonstrate that operation of the bioslurper system in the drawdown mode was effective, but may not be sustainable.

Groundwater production rates during bioslurping were significantly higher than rates during the skimmer or drawdown pump tests. The average rate was 2,200 gallons/day, with a total recovery of 6,795 gallons. Contaminant concentrations in groundwater were low and groundwater was able to be discharged to the Base Industrial Wastewater Treatment Plant.

Bioslurping also promotes mass removal in the form of volatilization and in situ biodegradation via aeration of the vadose zone. Vapor phase mass removal is the result of soil gas extraction as well as volatilization that may occur during the movement of free-phase LNAPL through the extraction network. Given, the measured vapor flowrate and vapor concentrations, initial hydrocarbon removal rates were approximately 21 lb/day of TPH and 0.023 lb/day of benzene. Thus, mass removal in the vapor phase is not significant.

In summary, the on-site testing at the North Tanks Area, Tinker AFB, included the direct testing of gravity-driven and vacuum-driven LNAPL free product recovery techniques, bioventing, physical sampling, and tests relevant to soil vapor extraction. Liquid-phase recovery was possible in all extraction modes, although slightly higher in the bioslurper mode than during skimmer or drawdown pumping. However, groundwater production during bioslurping was significant and could pose a logistical problem for the Base. Skimmer pumping appeared to be effective at free-product recovery, while generation 10% of the groundwater produced during bioslurping. Therefore, skimmer pumping is probably a better option for free-product recovery at this site.

4.0 REFERENCES

Battelle. 1995. Test Plan and Technical Protocol for Bioslurping, Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. Test Plan and Technical Protocol for a Field Treatability Test for Bioventing (Rev. 2), Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc. for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

APPENDIX A

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT TINKER AFB, OKLAHOMA

SITE-SPECIFIC TEST PLAN FOR FREE-PRODUCT RECOVERY TESTING AT TINKER AIR FORCE BASE, OKLAHOMA

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TINKER AFB, OKLAHOMA

NOVEMBER 8, 1996

SITE-SPECIFIC TEST PLAN FOR FREE-PRODUCT RECOVERY TESTING AT TINKER AIR FORCE BASE, OKLAHOMA CONTRACT NO. F41624-94-C-8012

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November 8, 1996

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE/ERT	Air Force Center for Environmental Excellence, Technology Transfer Division
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
ERA	Expedited Response Action
gpd	gallons per day
LNAPL	light, nonaqueous-phase liquid
ND	not detected
NPL	National Priorities List
NTA	North Tank Area
PCE	tetrachloroethene
POC	Point of Contact
POL	petroleum, oil, and lubricants
TCE	trichloroethene
TPH	total petroleum hydrocarbons
TPH-D	total petroleum hydrocarbons as diesel
UST	underground storage tank

SITE-SPECIFIC TEST PLAN FOR FREE-PRODUCT RECOVERY TESTING
AT TINKER AIR FORCE BASE, OKLAHOMA

DRAFT

to

Air Force Center for Environmental Excellence
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November 8, 1996

1.0 INTRODUCTION

The AFCEE/ERT is conducting a multi-site initiative to develop more effective methods of determining the feasibility of light, nonaqueous-phase liquid (LNAPL) free-product recovery as well as the best method of recovery. The technologies tested in the Bioslurper Initiative are skimming, vacuum-enhanced free-product recovery/bioremediation (bioslurping), and drawdown pumping. The field test and evaluation are intended to demonstrate the initial feasibility of each technology by measuring system performance in the field. System performance parameters, mainly free-product recovery, will be determined at numerous sites. Field testing will be performed at many sites to determine the effects of different organic contaminant types and concentrations and different geological conditions on free-product recovery effectiveness.

Plans for the field test activities are presented in two documents. The first is the overall Test Plan and Technical Protocol for the entire program entitled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall plan is supplemented by plans specific to each test site. The concise site-specific plans effectively communicate planned site activities and operational parameters.

The overall Test Plan and Technical Protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of site-specific Test Plan preparation. The field program involves installation and operation of the bioslurping system supported by a wide variety of site characterization, performance monitoring, and chemical analysis activities. The basic methods to be applied from site to site do not change. Preparation and review of the overall Test Plan and Technical Protocol allows efficient documentation and review of the basic approach to the

test program. Peer and regulatory review were performed for the overall Test Plan and Technical Protocol to ensure the credibility of the overall program.

This report is the site-specific Test Plan for application of bioslurping at Tinker Air Force Base (AFB), Oklahoma. It was prepared based on site-specific information received by Battelle from Tinker AFB and other pertinent site-specific information to support the overall Test Plan and Technical Protocol.

Site-specific information for Tinker AFB has identified subsurface hydrocarbon contamination both at the North Tank Area (NTA) and at Tank 290. Free-product thicknesses of greater than 10 ft have been found at NTA-8A, NTA-10A, NTA-11A, 1-30, and RC-4; therefore, these wells will be the most likely candidates for free-product recovery testing in the North Tank Area. Based on limited information on the Tank 290 site, the most likely wells for free-product recovery testing are MF-12 and 2-46B. These wells have recently shown product thicknesses of 1.2 ft and 0.4 ft, respectively.

2.0 SITE DESCRIPTION

Tinker AFB is located southeast of Oklahoma City in central Oklahoma and occupies 4,541 acres. It is bound to the north and west by residential, industrial, and commercial land uses and to the south and east by agricultural land uses.

2.1 North Tank Area

The North Tank Area (NTA), operative since 1943, is located north of Building 3001 and is used as an informal staging area (Figurel). Building 3001 was placed on the National Priorities List (NPL) in 1987, and the NTA has been designated as an operable unit of the Building 3001 site.

Five underground storage tanks (USTs) have at one time stored various liquid fuels at the NTA; however, four USTs have since been removed leaving only one remaining active tank. Tank 3401 is a 20,000-gallon diesel tank installed in 1972 to replace a previously existing tank and is still operative. USTs which have been removed from the site include Tank 3403, Tank 3404, and Tank 3405, which were used to contain waste oil, No. 2 fuel oil, and gasoline respectively. An unnumbered sump tank was also removed from the site. Refer to Figure 1 for tank locations. Slow chronic leaks were known to exist in Tanks 3404 and 3405. Other primary contaminants at the site include trichloroethane (TCE) and chromium resulting from solvents and liquid wastes from Building 3001.

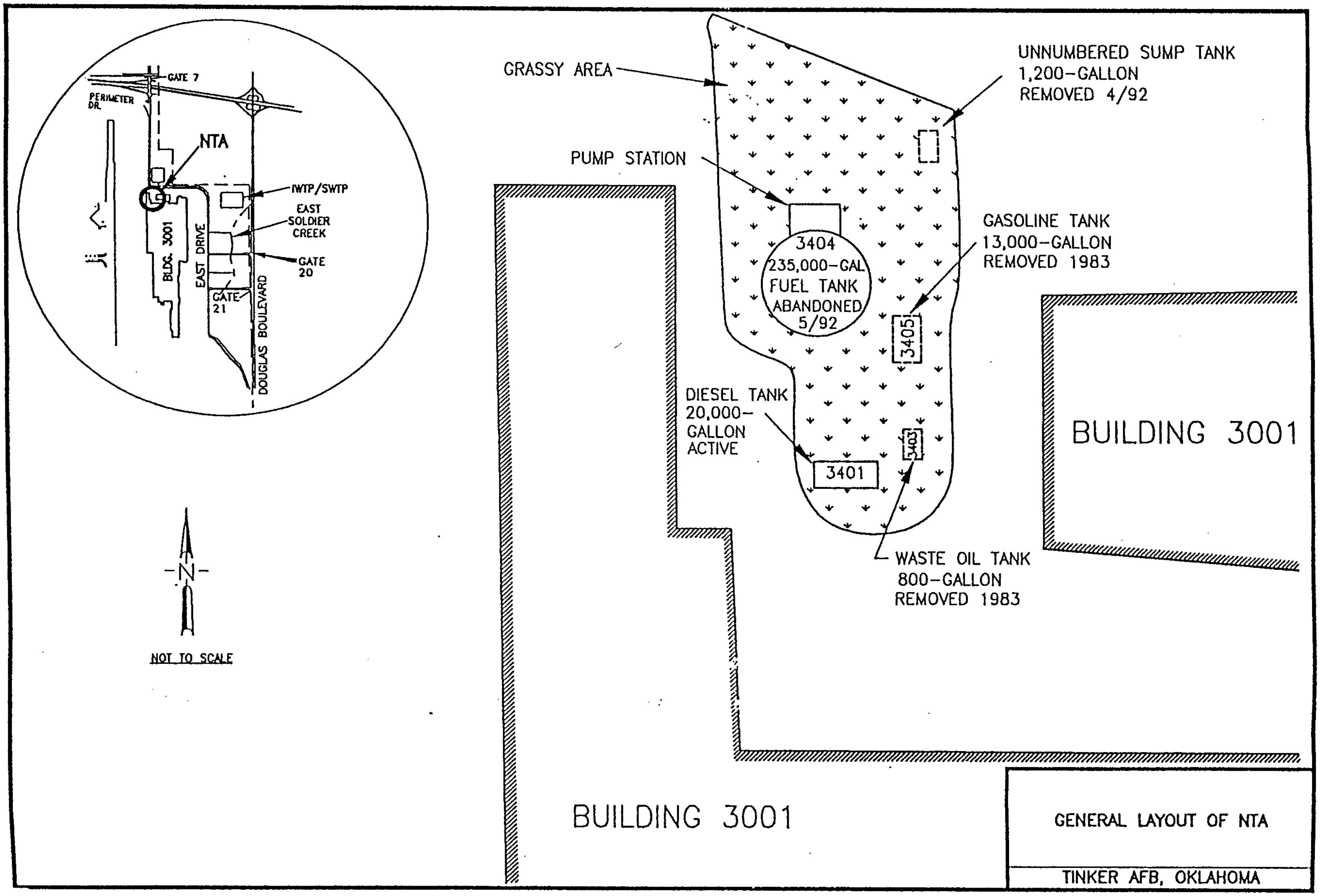


Figure 1. General Layout of NTA, Tinker AFB, Oklahoma

The uppermost stratigraphic unit underlying the NTA is a low-permeability surficial clay unit ranging from 6 to 10 ft in thickness. Below the surficial clay unit is a 5- to 11-ft upper sandy layer consisting primarily of silty sand to poorly graded sand. An upper shale unit consisting of weathered shale and siltstone underlies the upper sand unit and is found at thicknesses of 3 to 11 ft. The next underlying unit is described as fine- to medium-grained cross-bedded sandstone and is referred to as the lower sandstone layer. A lower shale unit which extends laterally across the entire NTA underlies the 7- to 16-ft thick lower sandstone unit. These five stratigraphic units represent a vertical depth of approximately 40 ft and correspond with hydrogeologic formations underlying the NTA. The upper shale layer acts as an upper confining layer, therefore resulting in an upper perched aquifer corresponding to the upper sand unit. Similarly, the lower shale unit serves as a lower confining layer, resulting in a lower perched aquifer which corresponds to the lower sandstone unit (Figure 2). Groundwater flow in the upper perched aquifer is primarily to the south and in the lower perched aquifer to the northwest and west. Locations and screened intervals of existing wells are detailed in Figure 3.

Soil analysis data reveals that total petroleum hydrocarbons as diesel (TPH-D) is found at greatest concentrations in the lower perched aquifer. A maximum TPH-D concentration of 130,000 mg/kg is found at NTA-10A and NTA-10B and decreases to the south and west with concentrations of approximately 10,000 mg/kg found at NTA-7A and NTA-7B. Concentrations are seen to decrease rapidly outside of the free-product zone. Benzene, toluene, ethylbenzene, and xylenes (BTEX) contamination in soil also tends to be highest in the lower perched aquifer and is most pronounced in the soil near Tank 3404. High concentrations of total xylenes, ethylbenzene, toluene, and benzene are 18,000 μg/kg, 10,000 μg/kg, 4,000 μg/kg, and 500 μg/kg respectively.

Groundwater data indicates TPH-D concentrations in the upper perched aquifer to be less than 0.5 mg/L and concentrations in the lower perched aquifer to be 10 mg/L in the free-product zone. Groundwater BTEX concentrations in the upper perched aquifer were generally below detection limits. The lower aquifer tends to have elevated benzene, ethylbenzene, and xylene concentrations in the vicinity of Tank 3401 and 3404 and elevated toluene concentrations near Tank 3401 and NTA-4A. Chlorinated ethene solvents are found at highest concentrations to the northwest of the NTA in both the upper and lower aquifers, with the most pronounced levels being found near NTA-4. Detected solvents include trichloroethene (TCE), tetrachloroethene (PCE), vinyl chloride, and *cis*-1,2-dichloroethene.

Free product has been observed in a 50,000-ft^2 area of the NTA and tends to be greater in the lower than in the upper perched aquifer. Free-product thicknesses tend to be greatest immediately

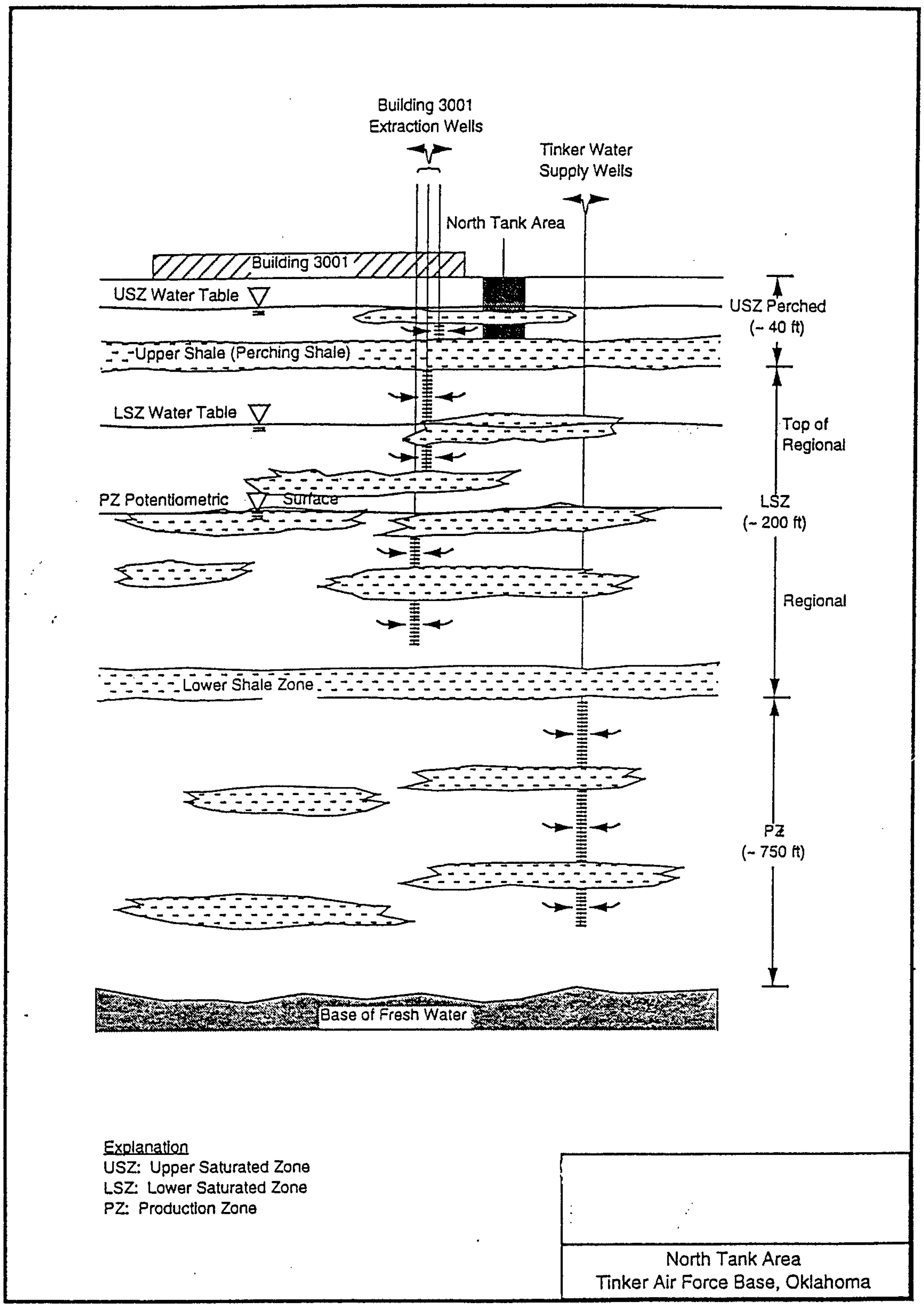


Figure 2. Cross Section of the Northeast Part of Tinker AFB, Oklahoma

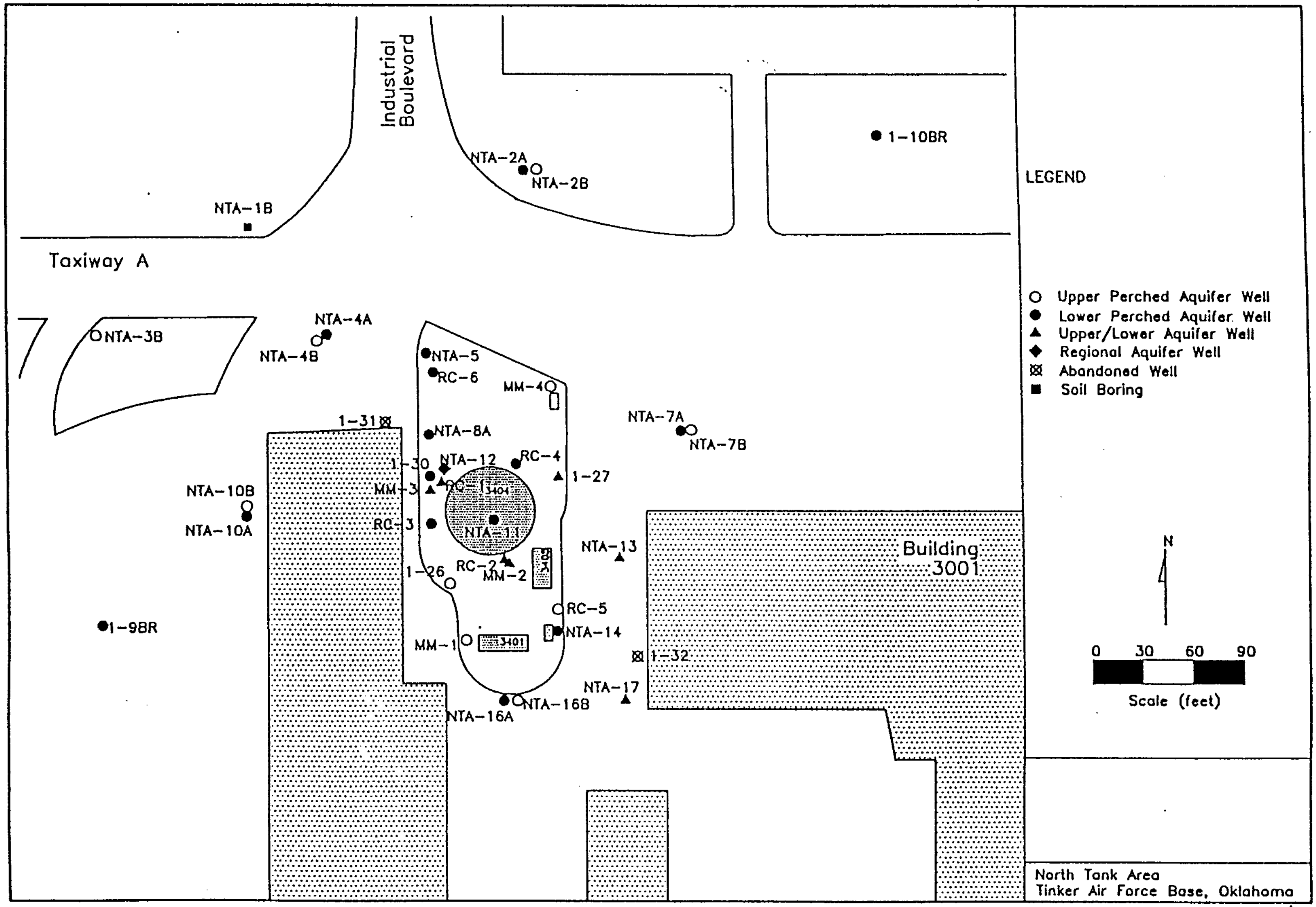


Figure 3. Existing Wells at NTA, Tinker AFB, Oklahoma

north of Tank 3404 and at the western boundary of the free-product area near NTA-10A. Wells with greater than 10 ft of apparent free product include NTA-8A, NTA-10A, NTA-11, 1-30, and RC-4. Product thickness measurements for individual wells can be found in Appendix A. Although various recovery operations have been in place since 1991, the primary pumping wells since 1994 have been RC-4, NTA-11, NTA-8, 1-30, and RC-3 which are all completed in the lower formation. Well construction details appear in Appendix B. One product-only pump has been operating almost constantly at RC-4, and another has been alternated between NTA-8 and NTA-11. The average daily production of product since 1994 has been 8 to 9 gallons per day (gpd). Free product is encountered at depths of 13 to 17 ft below ground surface (bgs) in the upper perched aquifer; however, free product is primarily recovered from wells screened at deeper intervals to recover free product which has been trapped beneath the upper shale layer.

2.2 POL Yard

The Tank 290 Fuel Farm was operative from 1942 to 1986 and recovery operations were begun in June of 1987 as an interim action. Figure 4 shows the layout of Tank 290 and the monitoring well network. The original system consisted of 4 pumps which recovered from monitoring wells MF-24 and MF-26. Average fuel recovery was approximately 10 gal/week. The system underwent modifications in 1988, after which time an auto-skimmer was used and extraction took place only from MF-24. Average fuel recovery following these modifications was approximately 17 gal/week. During the operational period from June of 1987 to December of 1988 a total of 1,450 gallons of fuel and 190,000 gallons of water were removed (U.S. Army Corps of Engineers, 1989). An Expedited Response Action (ERA) report estimated 50,000 gallons of free product at the site; however, this calculation was based on apparent product thicknesses. The amount should be revised to 12,500 gallons to reflect actual thicknesses (U.S. Army Corps of Engineers, 1989).

Previous investigations indicate that contamination is only in the perched aquifer and that the regional aquifer seems to remain unaffected. Groundwater flow in the regional aquifer is generally to the southwest. Monitoring wells where free product has recently been measured include MF-12 and 2-46B. Respective thicknesses of 1.2 ft and 0.4 ft were found at these wells in October 1996.

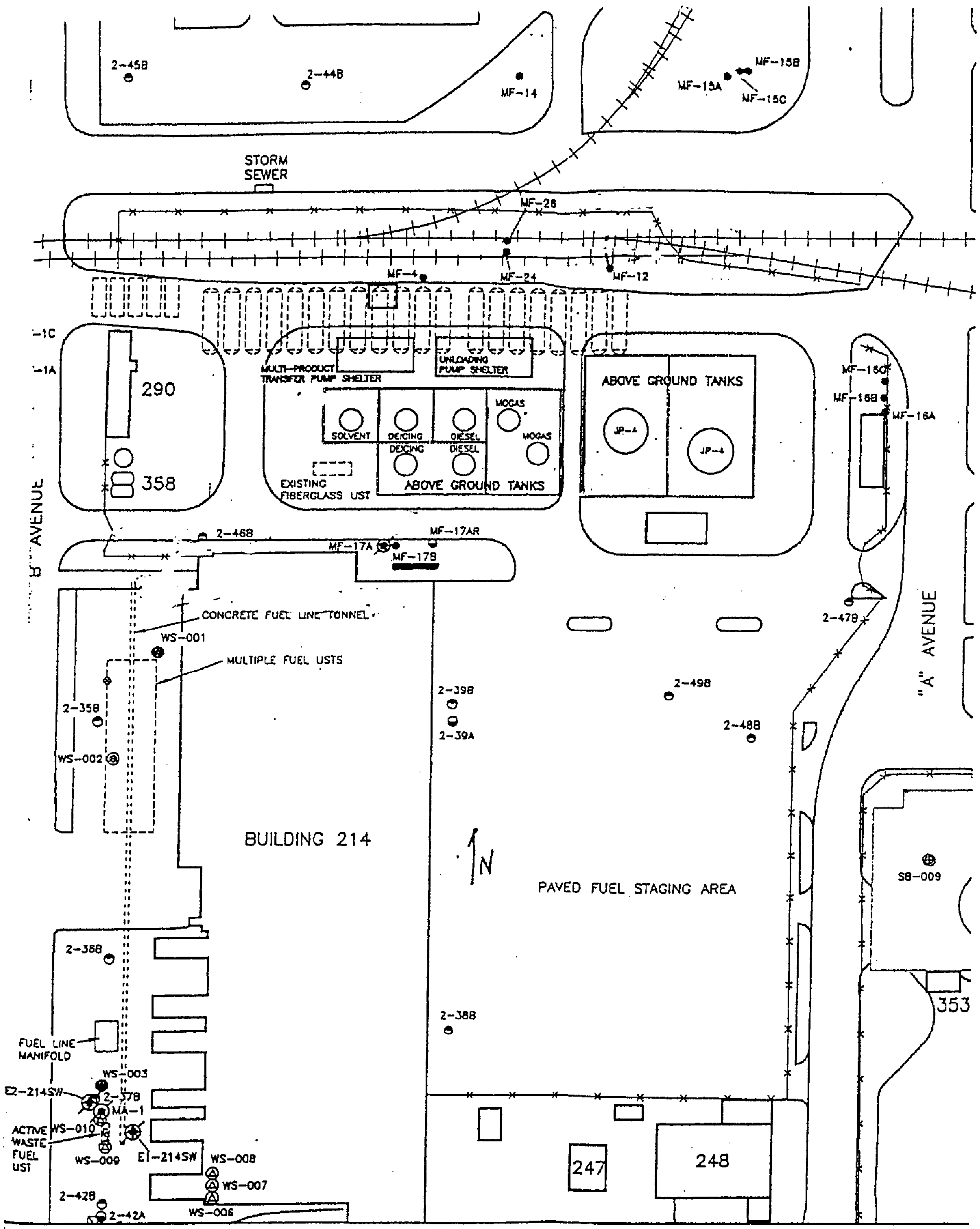


Figure 4. Tank 290 Layout and Monitoring Well Network, Tinker AFB, Oklahoma

3.0 PROJECT ACTIVITIES

The field activities discussed in the following sections are planned for the free-product recovery pilot test at Tinker AFB. Additional details about the activities are presented in the overall Test Plan and Technical Protocol (Battelle, 1995). As appropriate, specific sections in the overall Test Plan and Technical Protocol are referenced. Table 1 presents the schedule of activities for the free-product recovery pilot test activities at Tinker AFB.

3.1 Mobilization to the Site

After the site-specific Test Plan is approved, Battelle staff will mobilize equipment to the site. Some of the equipment will be shipped via air express to Tinker AFB prior to staff arrival. The Base Point of Contact (POC) will have been asked in advance to find a suitable holding facility to receive the free-product recovery pilot test equipment so that it will be easily accessible to the Battelle staff when they arrive with the remainder of the equipment. The exact mobilization date will be confirmed with the Base POC as far in advance of fieldwork as is possible. The Battelle POC will provide the Base POC with information on each Battelle employee who will be on site. Battelle personnel will be mobilized to the site after confirmation that the shipped equipment has been received by Tinker AFB.

3.2 Site Characterization Tests

3.2.1 Baildown Tests

The baildown test is the primary test for selection of the bioslurper test well. Baildown tests are also useful for the evaluation of actual versus apparent free-product thicknesses. Baildown tests will be performed at wells that contain measurable thicknesses of LNAPL to estimate the LNAPL recovery potential at those particular wells. In most cases, the well exhibiting the highest rate of LNAPL recovery will be selected as the bioslurper extraction well. A sample of free LNAPL will be collected at this point for analyses of boiling point distribution and BTEX concentration. Detailed procedures for the baildown tests are provided in Section 5.6 of the overall Test Plan and Technical Protocol (Battelle, 1995).

Table 1. Schedule of Bioslurper Pilot Test Activities

Pilot Test Activity	Schedule
Mobilization	Days 1-2
Site Characterization	Days 2-3
LNAPL/Groundwater Interface Monitoring and Baildown Tests	
Monitoring Point Installation (3 monitoring points)	
Soil Sampling (BTEX, TPH, physical characteristics)	
System Installation	Days 2-3
Test Startup	Day 3
Skimmer Pump Test (2 days)	Days 3-4
Bioslurper Pump Test (4 days)	Days 5-8
Soil Gas Permeability Testing	Day 5
Skimmer Pump Test (continued)	Day 9
In Situ Respiration Test - Air/Helium Injection	Day 9
In Situ Respiration Test - Monitoring	Days 10-13
Drawdown Pump Test (2 days)	Days 10-11
Demobilization/Mobilization	Days 12-13

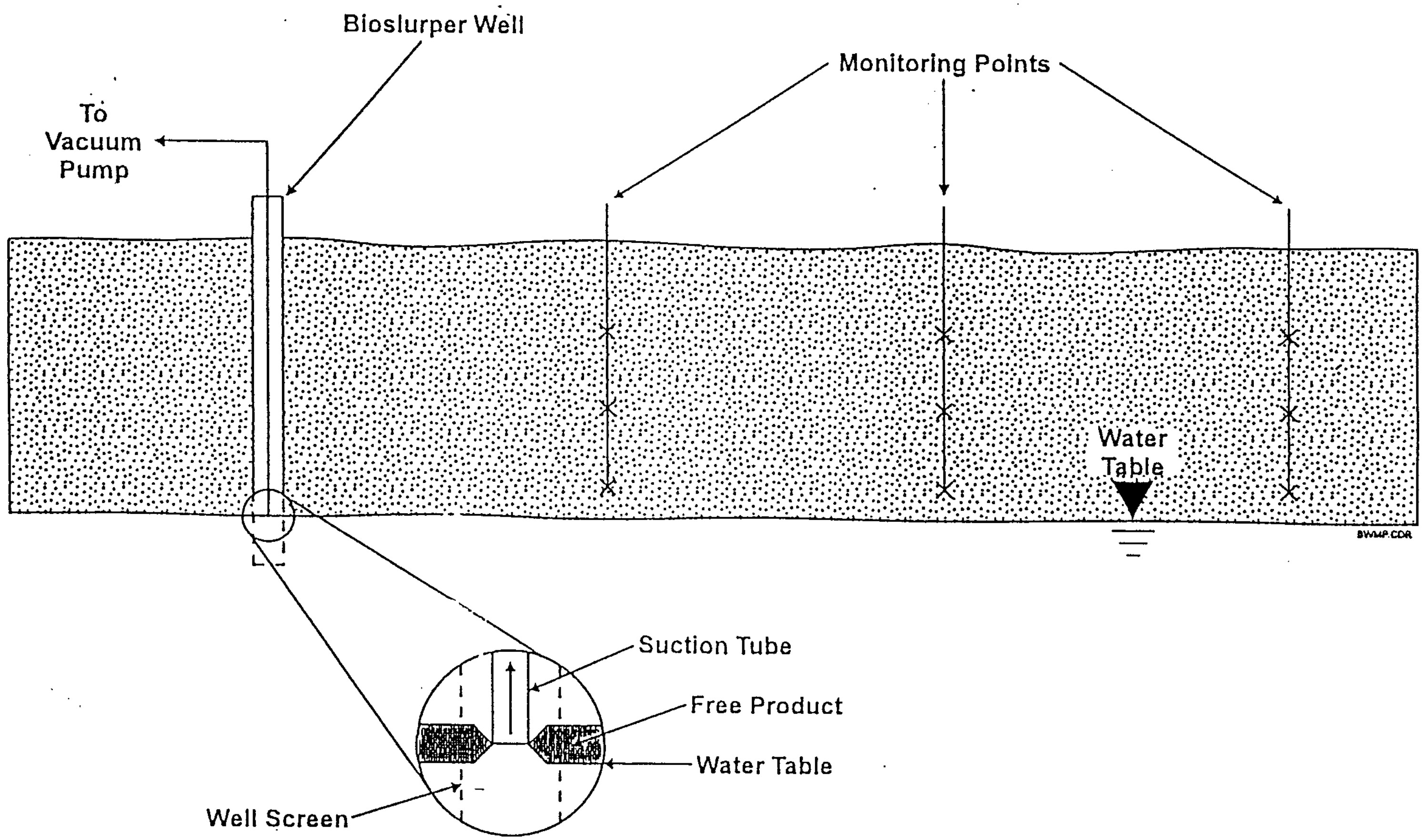


Figure 5. General Bioslurper Well and Monitoring Point Arrangement

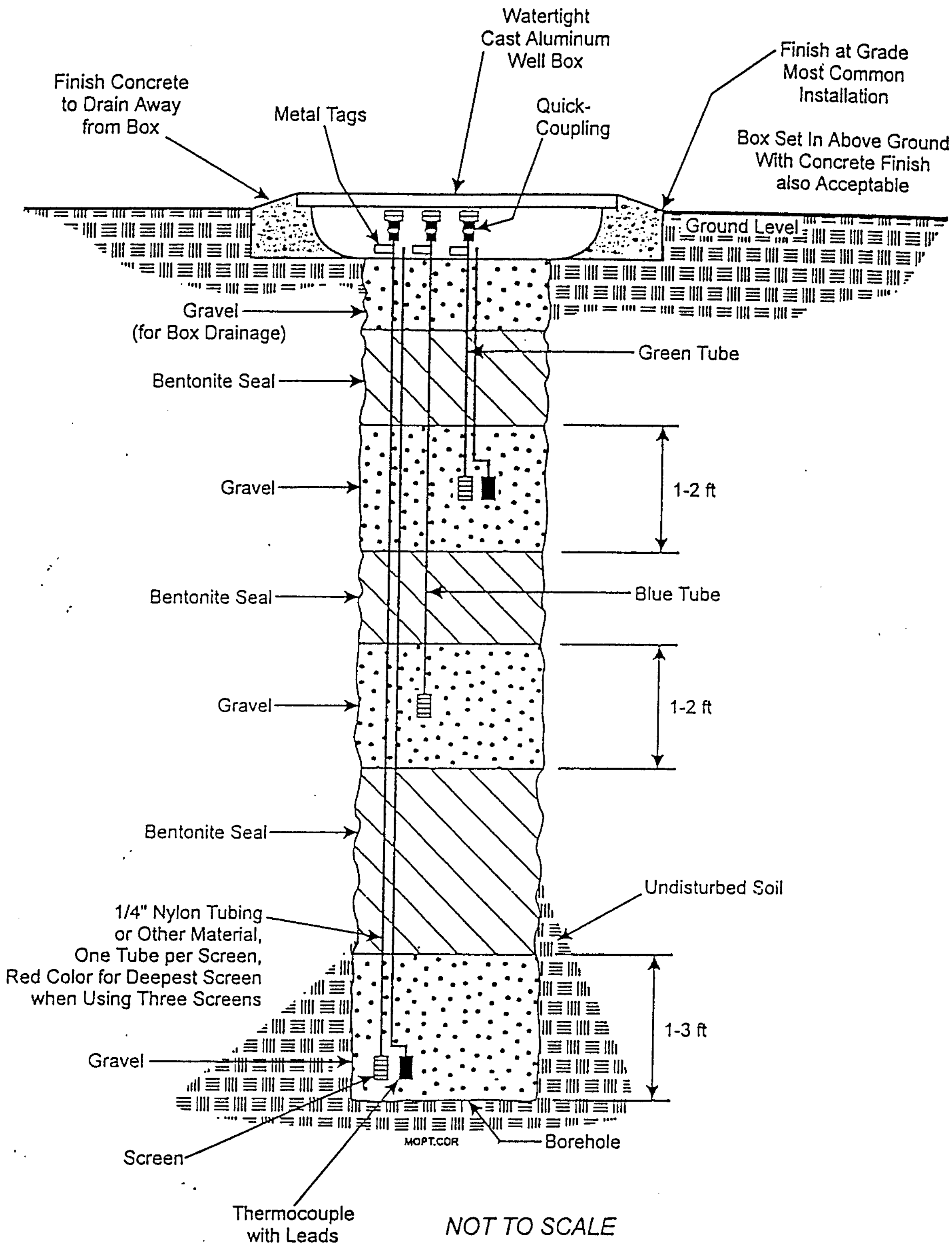


Figure 6. Schematic Diagram of a Typical Monitoring Point

3.2.2 Monitoring Point Installation

Monitoring points must be installed to determine the radius of influence of the bioslurper system in the vadose zone. A general arrangement of the bioslurping well and monitoring points is shown in Figure 5. Upon completion of the baildown tests, at least three soil gas monitoring points will be installed (unless existing monitoring points are available for use) to measure soil gas changes that occur during bioslurper operation. These monitoring points should be located in highly contaminated soils within the free-phase plume and should be positioned to allow detailed monitoring of the in situ changes in soil-gas composition caused by the bioslurper system. A schematic diagram of a typical monitoring point is shown in Figure 6. Information on monitoring point installation can be found in Section 4.2.1 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.2.3 Soil Sampling

Soil samples will be collected from each boring to determine the physical and chemical composition of the soil near the bioslurper test site. Soil samples will be collected from the boreholes advanced for monitoring point installation at two or three locations at the site chosen for the bioslurper test. Generally, samples will be collected from the capillary fringe over the free product.

Soil samples from each boring will be analyzed for BTEX, bulk density, moisture content, particle size distribution, porosity, and TPH. Section 5.5.1 of the overall Test Plan and Technical Protocol (Battelle, 1995) contains additional information on field measurements and sample collection procedures for soil sampling.

3.3 Bioslurper System Installation and Operation

Once the well to be used for the free-product recovery pilot test installation at Tinker AFB has been identified, the bioslurper pump and support equipment will be installed, and pilot testing will be initiated.

3.3.1 System Setup

After the preliminary site characterization has been completed and the free-product recovery candidate well has been selected, the shipped equipment will be mobilized from the holding facility to

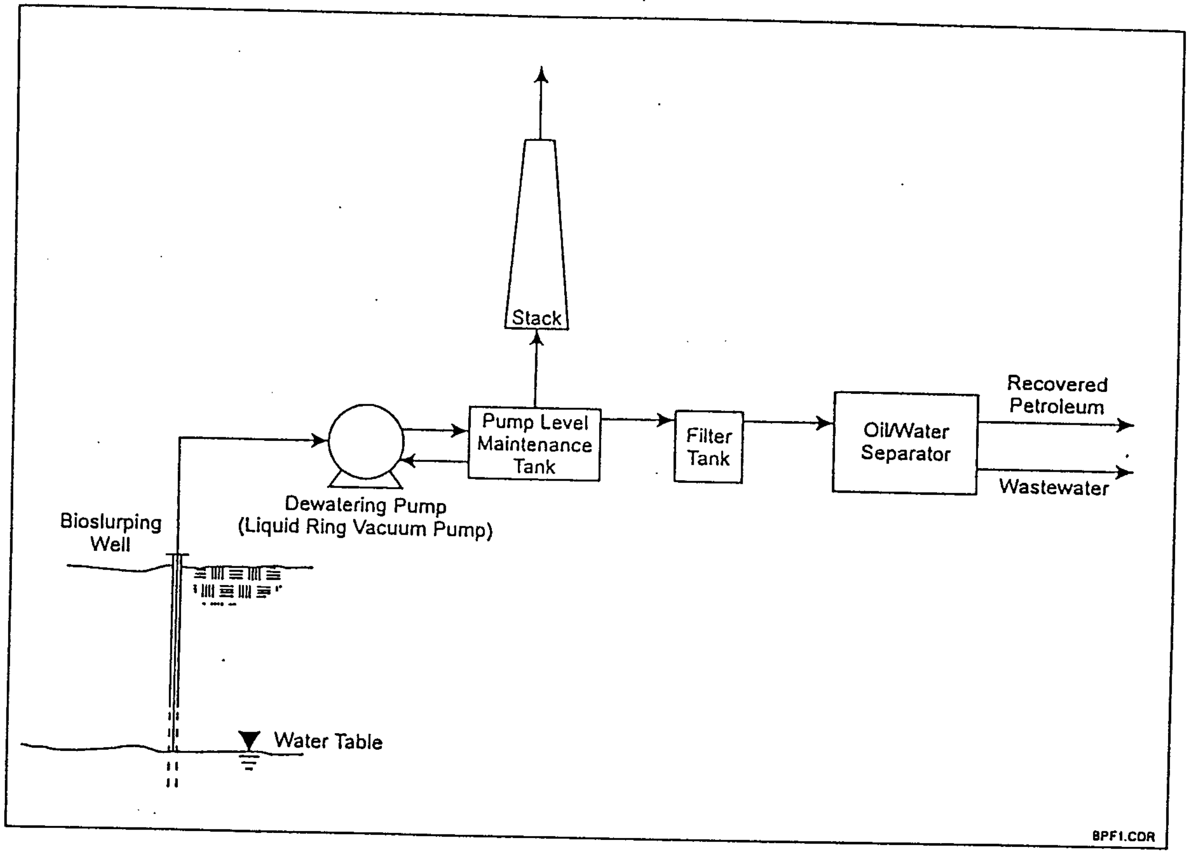


Figure 7. Bioslurper Process Flow at Tinker AFB, Oklahoma

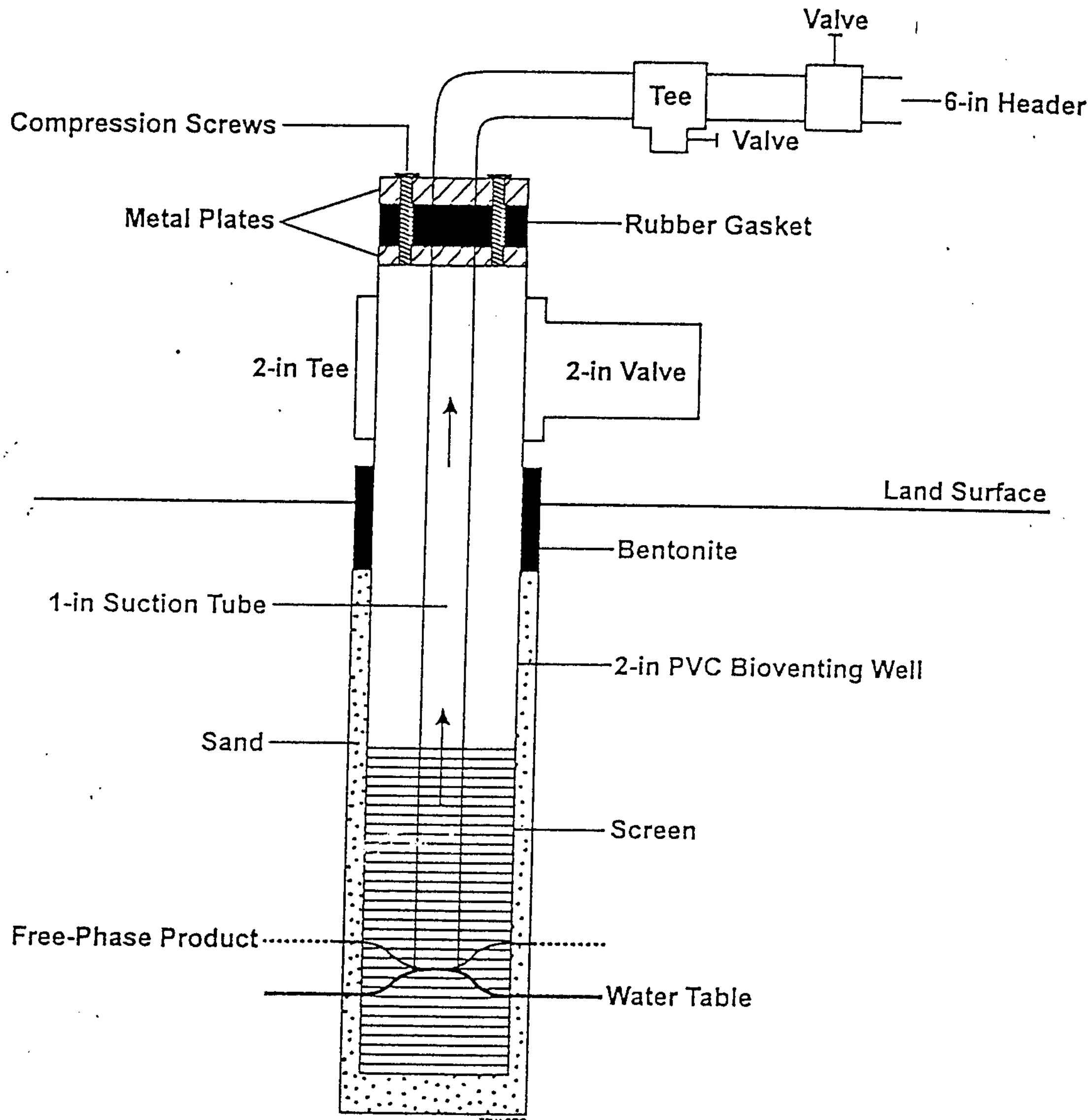


Figure 8. Schematic Diagram of a Typical Bioslurper Well

the test site, and the bioslurper system will be assembled. Figure 7 shows a flow diagram of the bioslurper process. Figure 8 illustrates a typical bioslurper well that will be used at Tinker AFB.

Before the LNAPL recovery tests are initiated, all relevant baseline field data will be collected and recorded. These data will include soil-gas concentrations, initial soil-gas pressures, the depth to groundwater, and the LNAPL thickness. Ambient soil and all atmospheric conditions (e.g., temperature and barometric pressure) also will be recorded. All emergency equipment (i.e., emergency shutoff switches and fire extinguishers) will be installed and checked for proper operation at this time.

A clear, level 20-ft by 10-ft area near the well selected for the free-product recovery pilot test installation will be identified to station the equipment required for bioslurper system operation. Additional information on bioslurper system installation is provided in Section 6.0 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.3.2 System Shakedown

A brief startup test will be conducted to ensure that the system is constructed properly and operates safely. All system components will be checked for problems and/or malfunctions. A checklist will be provided to document the system shakedown.

3.3.3 System Startup and Test Operations

After installation is complete and the bioslurper system is confirmed to be operating properly, the LNAPL recovery tests will be started. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as an LNAPL recovery test technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative includes three separate LNAPL recovery tests: (1) a skimmer pump test, (2) a bioslurper pump test, and (3) a drawdown pump test. The three recovery tests are described in detail in Section 7.3 of the overall Test Plan and Technical Protocol (Battelle, 1995).

The bioslurper system operating parameters that will be measured during operation are vapor discharge composition, aqueous effluent contaminant concentration, LNAPL recovery volume rates, vapor discharge volume rates, and groundwater discharge volume rates. Vapor monitoring will consist of periodic monitoring of TPH using hand-held instruments supplemented by two samples collected for detailed laboratory analysis. Two samples of aqueous effluent will be collected for analysis of BTEX and TPH. Recovered LNAPL volume will be recorded using an in-line flow-

totalizing meter. The off-gas discharge volume will be measured using a calibrated pitot tube, and the groundwater discharge volume will be recorded using an in-line flow-totalizing meter. Section 8.0 of the overall Test Plan and Technical Protocol (Battelle 1995) describes process monitoring of the bioslurper system.

3.3.4 Soil-Gas Profile/Oxygen Radius of Influence Test

Changes in soil-gas profiles will be measured before and during the bioslurper pump test. Soil gas will be monitored for concentrations of oxygen, carbon dioxide, and TPH using field instruments. These measurements will be used to determine the oxygen radius of influence of the bioslurper system.

3.3.5 Soil-Gas Permeability Tests

A soil-gas permeability test will be conducted concurrently with startup of the bioslurper pump test. Soil-gas permeability data will support the process of estimating the vadose zone radius of influence of the bioslurper system. Soil-gas permeability results also will aid in determining the number of wells required if it is decided to treat the site with a full-scale bioslurper system. The soil-gas permeability test method is described in Section 5.7 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.3.6 LNAPL and Groundwater Level Monitoring

During the bioslurper pump test, the LNAPL and groundwater levels will be monitored in a well adjacent to the extraction well if such a well exists. The top of the monitoring well will be sealed from the atmosphere so the subsurface vacuum will be contained. Additional information for the monitoring of fluid levels is provided in Section 4.3.4 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.3.7 In Situ Respiration Test

An in situ respiration test will be conducted after completion of the free-product recovery pilot tests. The in situ respiration test will involve injection of air and helium into selected soil-gas

monitoring points followed by monitoring changes in concentrations of oxygen, carbon dioxide, TPH, and helium in soil gas at the injection point. Measurement of the soil-gas composition typically will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours for about 2 days. The timing of the tests will be adjusted based on the oxygen-use rate. If oxygen depletion occurs rapidly, more frequent monitoring will be required. If oxygen depletion is slow, less frequent readings will be acceptable. The oxygen utilization rate will be used to estimate the biodegradation rate at the site. Further information on the procedures and data collection of the in situ respiration test is provided in Section 5.8 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.4 Demobilization

Once all necessary tests have been completed at the Tinker AFB site, the equipment will be disassembled by Battelle staff. The equipment then will be moved back to the holding facility, where it will remain until its next destination is determined. Battelle staff will receive this information and will be responsible for shipment of the equipment to the next site before leaving Tinker AFB.

4.0 BIOSLURPER SYSTEM DISCHARGE

4.1 Vapor Discharge Disposition

Battelle expects that the operation of the bioslurper test system at Tinker AFB will require a waiver or a point source air release registration and may require some additional permits. It can be estimated that approximately 60 lb/day of TPH and <0.1 lb/day of benzene will be released to the atmosphere without treatment. These values are based on the average discharge rates at previous bioslurper test sites. These values were based on sites with more volatile fuels, however, it is likely that Tinker AFB also contains heavier fuels which will result in decreased vapor discharge levels. The discharge value may vary depending on concentrations in soil gas and the permeability of the soil. The data for benzene and TPH discharge levels for 8 previous bioslurper sites are presented in Table 2.

To ensure the safety and regulatory compliance of the bioslurper system, field soil-gas screening instruments will be used to monitor vapor discharge concentration. The volume of vapor discharge will be monitored daily using airflow instruments. If state regulatory requirements will not permit the expected amount of organic vapor discharge to the atmosphere, the Base POC should

inform AFCEE and Battelle so that alternative plans can be made prior to mobilization to the site. Table 3 presents information typically required to complete an air release registration form.

Table 2. Benzene and TPH Vapor Discharge Levels at Previous Bioslurper Test Sites

Site Location	Fuel Type	Extraction Rate (scfm)	Benzene (ppmv)	TPH (ppmv)	Benzene Discharge (lb/day)	TPH Discharge (lb/day)
Andrews AFB	No. 2 Fuel Oil	8.0	16	2,000	0.0010	0.20
Bolling AFB, Site 1	No. 2 Fuel Oil	4.0	0.20	153	0.00030	0.0090
Bolling AFB, Site 2	Gasoline	21	370	70,000	2.3	470
Johnston Atoll	JP-4 Jet Fuel	10	0.60	975	0.0017	5.7
Travis AFB	JP-4 Jet Fuel	20	100	10,800	0.58	130
Wright-Patterson AFB	JP-4 Jet Fuel	3.0	ND	595	0	1.0
Warner Robins AFB, UST 70/72	JP-4 Jet Fuel	5.0	515	37,000	0.74	110
Warner Robins AFB, SS010	JP-4 Jet Fuel	5.5	13	680	0.021	2.2

ND = Not detected.

Table 3. Air Release Summary Information

Data Item	Air Release Information
Contractor Point-of-Contact	Jeff Kittel, (614) 424-6122
Contractor address	Battelle, 505 King Avenue, Columbus, OH 43201
Estimated total quantity of petroleum product to be recovered	To be determined
Description of petroleum product to be recovered	North Tank Area - No. 2 Fuel Oil, Gasoline
Planned date of test start	To be determined
Test duration	9-10 days (active pumping) per site
Maximum expected volatile organic compound level in air	~60 lb/day TPH, < 1.0 lb/day benzene
Stack height above ground level	10 ft

4.2 Aqueous Influent/Effluent Disposition

The flowrate of groundwater pumped by the bioslurper will be less than 10 gpm. However, it may be necessary in Oklahoma to obtain a groundwater pumping waiver or registration permit. If one is required, the Base POC will inform Battelle of the necessary steps in obtaining the waiver or permit. The intention of Battelle staff will be to dispose of the wastewater by discharge directly to the Base wastewater treatment facility.

4.3 Free-Product Recovery Disposition

The bioslurper system will recover free-phase product from the pilot tests performed at Tinker AFB. Recovered free product will be turned over to the Base for disposal and/or recycling. The volume of free product recovered from the Base will not be known until the tests have been performed. The maximum recovery rate for this system is 10 gpm, but the actual rate of LNAPL recovery likely will be much lower.

5.0 SCHEDULE

The schedule for the bioslurper fieldwork at Tinker AFB will depend on approval of the project Test Plan. Battelle will determine a definitive schedule as soon as possible after approval is received. Battelle will have two to three staff members on site for approximately 3 weeks to conduct all necessary pilot testing. At the conclusion of the field testing at Tinker AFB, all staff will return their Base passes. Battelle staff will remove all bioslurper field testing equipment from the Base before they leave the site.

6.0 PROJECT SUPPORT ROLES

This section outlines some of the major functions of personnel from Battelle, Tinker AFB, and AFCEE during the free-product recovery pilot test.

6.1 Battelle Activities

The obligations of Battelle in the Bioslurper Initiative at Tinker AFB will be to supply the staff and equipment necessary to perform all the tests on the bioslurper system. Battelle also will provide technical support in the areas of water and vapor discharge permitting, digging permits, and any other technical areas that need to be addressed.

6.2 Tinker AFB Support Activities

To support the necessary field tests at Tinker AFB, the Base must be able to provide the following:

a. Any digging permits and utility clearances that need to be obtained prior to the initiation of the fieldwork. Any underground utilities should be clearly marked to reduce the chance of utility damage and/or personal injury during soil-gas monitoring point and possible well installation. Battelle will not begin field operations without these clearances and permits.

b. The Air Force will be responsible for obtaining Base and site clearance for the Battelle staff that will be working at the Base. The Base POC will be furnished with all necessary information on each staff member at least one week prior to field startup.

c. Access to the local sanitary sewer must be furnished so that Battelle staff can discharge the bioslurper aqueous effluent directly to the Base treatment facility.

d. Regulatory approval, if required, must be obtained by the Base POC prior to startup of the bioslurper pilot test. As stated previously, it is likely that a waiver or permit to allow air releases or a point source air release registration will be required for emissions of approximately 60 lb/day of TPH and <1.0 lb/day benzene without treatment. A waiver for pumping and discharging groundwater at a rate of 10 gpm may be required. The Base POC will obtain all necessary Base permits prior to mobilization to the site.

e. The Base also will be responsible for the disposition of all waste generated from the pilot testing. Such waste includes any soil cuttings generated from drilling and all aqueous wastestreams produced from the free-product recovery tests. All free product recovered from the bioslurper operation will be disposed of or recycled by the Base. Battelle will provide technical assistance in disposing of the waste generated from the bioslurper pilot test.

f. Before field activities begin, the Health and Safety Plan will be finalized with information provided by the Base POC. Table 4 is a checklist for the information required to complete the Health and Safety Plan. All emergency information will be obtained by the Site Health and Safety Office before operations begin.

6.3 AFCEE Activities

The AFCEE POC will act as a liaison between Battelle and Tinker AFB staff. The AFCEE POC will ensure that all necessary permits are obtained and the space required to house the bioslurper field equipment is found.

6.4 Points of Contact

The following is a listing of Battelle, AFCEE, and Tinker AFB staff who can be contacted in case of emergency and/or for required technical support during the Bioslurper Initiative free-product recovery tests at Tinker AFB.

Battelle POCs	Jeff Kittel	(614) 424-6122
AFCEE POC	Patrick Haas	(210) 536-4314
Tinker AFB POC		
Regulatory POCs		

Table 4. Health and Safety Information Checklist

Emergency Contacts	Name	Telephone Number
Hospital	Emergency Room	(405) 734-8249
Fire Department	Emergency Switchboard	911/737-1117/117 (Base)
Ambulance and Paramedics	Emergency Switchboard	911
Police Department	Emergency Switchboard	911
EPA Emergency Response Team	Switchboard	(800) 424-8802
Program Contacts		
Air Force	Patrick Haas	(210) 536-4314
Battelle	Jeff Kittel	(614) 424-6122
Tinker AFB		
Other		
Emergency Routes		
Hospital Map attached in Appendix C		
Other		

7.0 REFERENCES

Battelle. 1995. *Test Plan and Technical Protocol for Bioslurping*. Prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Engineering-Science, Inc. and Battelle. 1994. *North Tank Area Focused Remedial Investigation Report, Tinker Air Force Base, Oklahoma*. Prepared by Engineering-Science, Inc. and Battelle Columbus Operations for Oklahoma City Air Logistics Center, Tinker Air Force Base, Oklahoma.

U.S. Army Corps of Engineers. 1989. *Tinker AFB POL Facility Report of Recovery Operations: June 1987 to December 1988*. Prepared by U.S. Army Corps of Engineers, Tulsa District for the Environmental Management Directorate, Department of the Air Force, Headquarters Oklahoma City Air Logistics Center.

APPENDIX A

APPARENT PRODUCT THICKNESS MEASUREMENTS AT NTA, TINKER AFB, OKLAHOMA

Table 5.15

Apparent Product Thickness Measurements (ft)

Well	Sampling Date 11/23/93	12/02/93	12/06/93
Upper Aquifer			
NTA-2B	no product	no product	no product
NTA-3B	no product	no product	no product
NTA-4B	no product	no product	no product
NTA-7B	no product	no product	no product
NTA-10B	no product	no product	no product
NTA-16B	no product	no product	no product
Lower/Undifferentiated Aquifer			
NTA-2A	no product	no product	no product
NTA-4A	no product	no product	no product
NTA-5	0.01	0.02	0.02
NTA-7A	0.11	0.13	0.13
NTA-8A	11.35	15.33	16.89
NTA-10A	19.86	19.46	19.20
NTA-11	7.14	11.81	12.18
NTA-13A	0.79	1.35	0.98
NTA-14	1.33	3.19	4.11
NTA-17	no product	no product	no product
NTA-16A	1.19	2.33	2.73
1-30	14.63	14.43[a]	14.32
MM-2	0.44	0.48	0.72
RC-3	2.68	6.53	8.39
RC-4	15.26	15.94	15.95
RC-5	0.18	0.49	0.74
RC-6	0.06	0.07	0.12
Top of Regional Aquifer			
NTA-12	no product	no product	no product

(a) Well may be filled with product; no water.

APPENDIX B

WELL CONSTRUCTION INFORMATION AT NTA,
TINKER AFB, OKLAHOMA

Table 3.1

Well Construction Information
North Tank Area, Tinker AFB, Oklahoma

Well Number	North Coordinates (feet)	East Coordinates (feet)	Drill Depth (feet)	Casing Dia. (in.)	Type of Casing	Screen Size (slot)	Screened Interval (feet)	Sand-Pack Interval (feet)	Monitored Hydrologic Unit	Drill Method	Casing Elevation	Surface Elevation
MM-1	156012.59	2185166.39	25	2	PVC	20	13 - 23	8.0 - 23	U Perched	HSA	1272.6	1273
MM-2	156059.78	2185196.21	26	2	PVC	20	15 - 25	12.0 - 25	U and L Perched	HSA	1273.2	1274
MM-3	156105.67	2185144.99	26.5	2	PVC	20	16.5 - 26.5	16 -26	U Shale	HSA	1272.2	1273
MM-4	156164.84	2185214.26	35	4	SS	10	10.0 - 20.0	8.0 - 22	U Perched	AR	1272.80	1272.80
1-26	156047.51	2185156.69	17	4	PVC	10	6.8 - 16.8	4.0 - 17	U Perched	HSA	1275.2	1272
1-27	156114.17	2185222.85	24	4	PVC	10	13.8 - 23.8	8.0 - 24	U and L Perched	HSA	1276.2	1273
1-30	156113.13	2185144.90	35.8	4	PVC	10	18 - 28	17.2 - 35.8	L Perched	HSA	1274.3	1272
1-31	156150.00	2185100.00	20.5	4	PVC	10	10.1 - 20.1	4.0 - 20.5	Abandoned	HSA	1274	1271'
1-32	155970.00	2185275.00	15	2	PVC	10	5.0 - 15	5.0 - 15	(Well Damaged)	HSA	1277	1274'
RC-1	156107.57	2185151.38	27	6	SS	10	15 - 25	12 - 25.5	U and L Perched	HSA	NA	1272'
RC-2	156062.57	2185189.82	27	6	SS	10	14.5 - 24.5	12 - 25.5	U and L Perched	HSA	NA	1272'
RC-3	156083.35	2185145.43	33	6	SS	10	22.5 - 32.5	21 - 33	L Perched	AR	1274.31	1271.91
RC-4	156121.07	2185196.99	34	6	SS	10	23.5 - 33.5	21 - 34	L Perched	AR	1275.61	1272.61
RC-5	156177.82	2185147.19	25	4	SS	10	10.0 - 20.0	8.0 - 22	U Perched	AR	1271.65	1271.65
RC-6	156030.75	2185221.86	34.5	4	SS	10	28 - 33	26 - 34.5	L Perched	AR	1274.09	1274.09
NTA-1B*	156272.66	2185038.84	20.0	n/a	n/a	n/a	n/a	n/a	n/a	HSA		
NTA-2A*	156304.78	2185203.24	38.0	4	SS	10	20.44 - 30.44	19.1 - 32.5	L Perched	HSA-AR		
NTA-2B*	156305.27	2185211.29	16.15	4	SS	10	10.3 - 15.4	8.4 - 16.15	U Perched	HSA		
NTA-3*	156201.25	2184943.79	18.75	4	SS	10	10.23 - 15.33	7.75 - 17.0	U Perched	HSA		
NTA-4A*	156202.28	2185082.30	40.0	4	SS	10	21.92 - 32.06	20.65 - 34.5	L Perched	HSA-AR		
NTA-4B*	156198.12	2185076.33	16.0	4	SS	10	10.26 - 15.66	8.0 - 16.0	U Perched	HSA		
NTA-5*	156190.74	2185143.02	50.0	4	SS	10	20.40 - 35.45	19.3 - 35.6	L Perched	HSA-AR		
NTA-7A*	156143.09	2185298.71	45.0	4	SS	10	23.30 - 38.30	21.90 - 38.0	L Perched	HSA-AR		
NTA-7B*	156143.35	2185305.01	18.3	4	SS	10	12.70 - 17.80	11.0 - 18.3	U Perched	HSA		
NTA-8A*	156140.27	2185144.49	35.0	4	SS	10	22.39 - 32.39	21.0 - 33.0	L Perched	HSA-AR		
NTA-10A*	156088.80	2185033.76	40.0	4	SS	10	23.0 - 33.0	21.8 - 36.0	L Perched	HSA-AR		
NTA-10B*	156095.17	2185034.01	16.4	4	SS	10	10.33 - 15.3	9.0 - 16.4	U Perched	HSA		
NTA-11*	156086.91	2185183.59	38.0	6	SS	10	22.28 - 32.28	19.8 - 35.4	L Perched	MR		
NTA-12*	156114.35	2185151.83	59.0	2	SS	10	40.7 - 55.7	37.75 - 56.5	Top-of-Regional (LSZ)	HSA-AR-MR		
NTA-13A*	156064.03	2185260.24	45.0	4	SS	10	13.94 - 34.00	11.6 - 36.0	U and L Perched	HSA		
NTA-14*	156018.24	2185221.54	40.0	4	SS	10	20.28 - 35.34	18.0 - 35.5	L Perched	HSA		

Table 3.1

Well Construction Information
North Tank Area, Tinker AFB, Oklahoma (Continued)

Well Number	North Coordinates (feet)	East Coordinates (feet)	Drill Depth (feet)	Casing Dia. (in.)	Type of Casing	Screen Size (slot)	Screened Interval (feet)	Sand-Pack Interval (feet)	Monitored Hydrologic Unit	Drill Method	Casing Elevation	Surface Elevation
NTA-16A*	155975.31	2185189.20	40.5	4	SS	10	20.78 - 31.10	18.8 - 32.1	L Perched	HSA-AR		
NTA-16B*	155975.30	2185197.56	16.4	4	SS	10	11.04 - 16.14	8 8 - 16.4	U Perched	HSA		
NTA-17*	155976.32	2185264.50	42.0	4	SS	10	14.02 - 29.05	12.1 - 33.1	U and L Perched	HSA		

Abbreviations/Notes

U = upper
SS = stainless steel
PVC = poly vinyl chloride
* Wells installed in 1993

L = lower
NA = data not available
NM = not measured
LSZ = Lower Saturated Zone

AR = air rotary
n/a = not applicable
HSA = hollow-stem auger

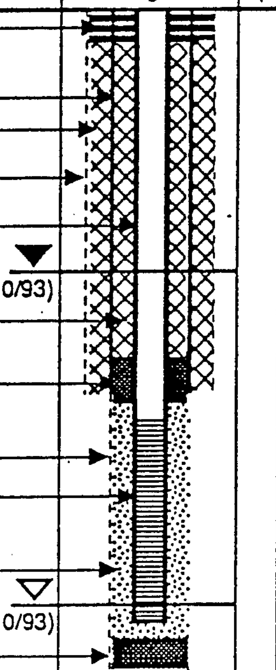
MR = mud rotary

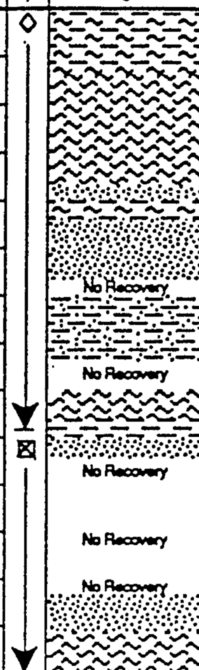
AS-BUILT DIAGRAM

Boring or Well Number NTA - 8A   Sheet 1 of 1
Location North Tanks, Tinker AFB   Project

Logged by SS Teel, JB Topping, CJ Perry, CA Payne   Date Well Started 10-13-93
Reviewed by   Date   Date Well Completed 10-28-93

Well Construction Data		Depth in Feet	Geologic / Hydrologic Data	
Description	Construction Diagram / Drill Bit		Sample Method / Lithologic Diagram	Lithologic Description





Well Construction Data – Description

- Concrete (4000 psi) (0-2') (flush completion w/manhole cover
- 8" Dia. Carbon Steel Casing (0-20')
- Cement Grout (2-20')
- 12" Dia. Borehole
- 4" Dia. Stainless Steel Casing (0.39 - 22.39')
- Depth to product (13.37', 12/10/93)
- Cement Grout(2-18')
- Bentonite Pellets (18-21')
- 7.88" Dia. Borehole
- 4" Dia. Stainless Steel Screen (22.39 - 32.89')
- Sandpack (21-33.0')
- Depth to water (31.70', 12/10/93)
- Bentonite Pellets (33-35')

Depth in Feet: 5, 10, 15, 20, 25, 30, 35, 40, 45

Lithologic Description

- Silty Clay (CL) (0-3.5')
- Clay (CL/CH) (3.5-5')
- Clay (CL/CH) (5-9')
- Sand (SP) (9-10')
- Silty Clay (CL) (10-11')
- Sand (SP) (11-14') — *10-15' recovery = 4'*
- No Recovery
- Sandy Shale (15-15.5)
- Sandy Silt (ML/MH) (15.5-18')
- No Recovery — *15-20' recovery = 3'*
- Claystone(20-21.5')
- Siltstone(21.5-22.5') — *20-25' recovery = 3.5'*
- Sandstone(22.5-23.5')
- No Recovery
- No Recovery — *25-30' recovery = none*
- No Recovery
- Sandstone(30.5-32.6') — *30-35' recovery = 4.5'*
- Claystone(Shale)(32.6-35.0')

Note: Depth of screen placement was determined after examining lithologic descriptions and geophysical logs.

All diameter measurements are nominal.

ASTM D 2488 classification shown in parenthesis

Drill Bit / Sample Method Used:
☐ Rotary ☒ Air Rotary ■ Mud Rotary ▲ Air Percussion △ Back Hoe ◇ Auger ○ Drive Barrel ● Hard Tool ⊕ Split-Barrel

A-1800-186 (12-91)

AS-BUILT DIAGRAM

Boring or Well Number NTA - 10A Sheet 1 of 1

Location Tinker AFB Project North Tank Area

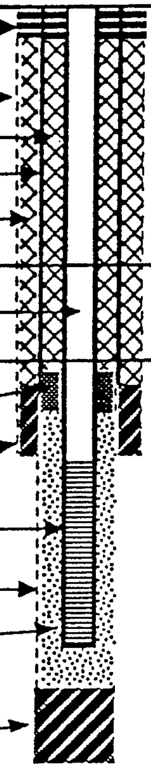
Logged by SS Teel, JB Topping, CJ Perry, CA Payne Date Well Started 10-22-93

Reviewed by ______ Date ______ Date Well Completed 11-4-93

Well Construction Data			Depth in Feet	Geologic / Hydrologic Data		
		Drill Bit		Sample Method		
Description	Construction Diagram				Lithologic Diagram	Lithologic Description

Well Construction Data – Description

- Concrete (4000 psi) (0 - 2') (flush completion w/manhole cover)
- 12" Dia. Borehole
- Cement Grout (2-19')
- 8" Dia. Carbon Steel Casing (0-20')
- Cement Grout (2-20')
- Depth to product (13.27', 12/10/93)
- 4" Dia. Stainless Steel Casing (-0.3-23')
- Depth to water (19.31', 12/10/93)
- Bentonite Pellets (19-21.8')
- Bentonite Hole Plug (20-23')
- 4" Dia. Stainless Steel Screen (23-33')
- 7.88" Dia. Borehole
- Sandpack (21.8-36')
- Bentonite Hole Plug (36-40')



Depth in Feet: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

Lithologic Description

- Concrete (0 - 0.5')
- No recovery (0.5 - 6')
- Gravelly Clay (CL/CH) (backfill?) (6-7')
- Silty Clay (CH) (7-8.5'), Clay (CH) (8.5-9.5')
- Sandy Silty Clay to Clayey Silty Sand (CL/CH to SM/SC) (9.5-13.5')
- Sand (SP-SM) (13.5-16')
- Silt (ML) (16-20')
- Shale (20-23')
- Sandstone (25-29')
- No recovery (29-30')
- Sandstone (30-33')
- No recovery (33-35')
- Claystone (35-40')

Note: Depth of screen placement was determined after examining lithologic descriptions and geophysical logs.

All diameter measurements are nominal.

ASTM D 2488 classification shown in parenthesis

Drill Bit / Sample Method Used:
☐ Rotary ☒ Air Rotary ■ Mud Rotary ▲ Air Percussion △ Back Hoe ◇ Auger ○ Drive Barrel ● Hard Tool ⊕ Split-Barrel

A-1800-186 (12-91)

AS-BUILT DIAGRAM

Boring or Well Number NTA - 11 Sheet 1 of 1

Location Tinker AFB Project North Tank Area

Logged by S S Teel, J B Topping, CJ Perry, CA Payne

Date Well Started 11-8-93

Reviewed by ______ Date ______

Date Well Completed 11-10-93

Well Construction Data | Depth in Feet | Geologic / Hydrologic Data

Drill Bit | Sample Method

Description

Concrete (0-2') (4000 psi) (flush completion w/manhole cover)

9-7/8-in. dia. borehole

6" Dia. Stainless Steel Casing (0.63 - 22.28')

Cement Grout Seal (2-17.3')

Depth to product (13.85', 12/10/93)

Bentonite Pellets (17.3-19.8')

Silica Sand (19.8-35.4')

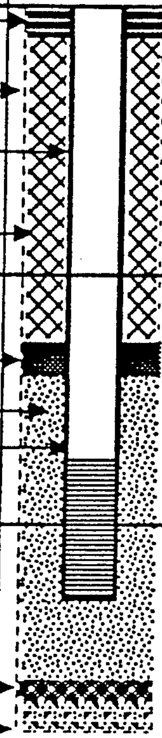
6" Dia. Stainless Steel Screen (22.28 - 32.28')

Depth to water (27.22', 12/10/93)

Bentonite Hole Plug (35.4 - 36.4')

Slough (36.4 - 38')

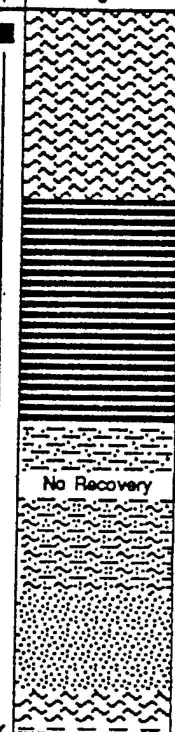
Construction Diagram



TD = 38 ft

Depth in Feet: 5, 10, 15, 20, 25, 30, 35, 40, 45, 50

Lithologic Diagram



Lithologic Description

Backfill Clay (CL/CH) (0 - 9.9')

Concrete (9.9-22')

Sandy Siltstone (22-23.8')

No recovery (23.8-26')

Clayey Sandy Siltstone (26-30.8')

Sandstone, well cemented, some silt and clay laminae (31-36')

Claystone (36-37.5)

Silt (37.5-38) (gradational contact with above claystone)

Note: Depth of screen placement was determined after examining lithologic descriptions and geophysical logs.

All diameter measurements are nominal.

ASTM D 2488 classification shown in parenthesis

Drill Bit / Sample Method Used:

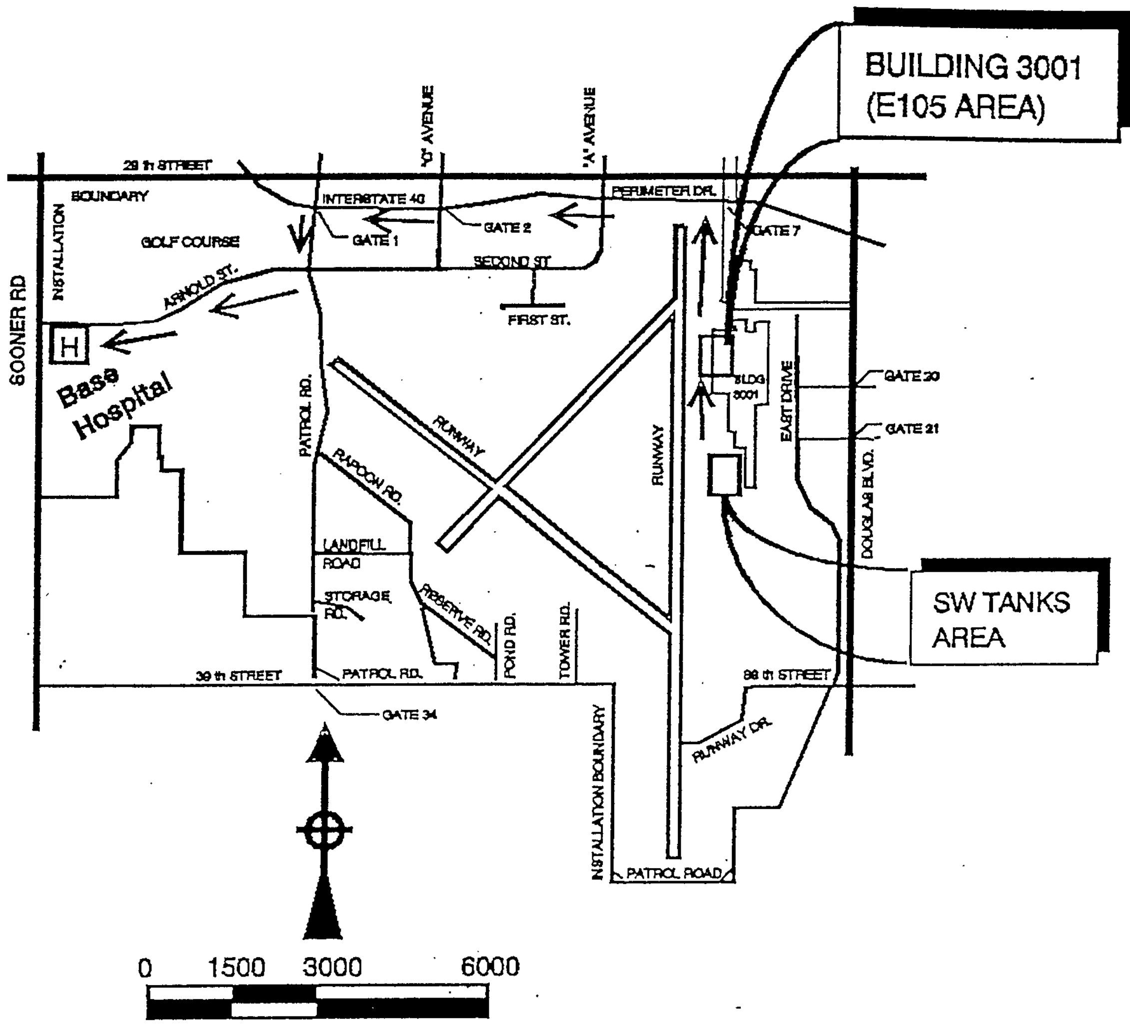
☐ Rotary ☒ Air Rotary ■ Mud Rotary ▲ Air Percussion △ Back Hoe ◇ Auger ○ Drive Barrel ● Hard Tool ⊕ Split-Barrel

A-1800-186 (12-91)

APPENDIX C

HOSPITAL LOCATION MAP

EMERGENCY ROUTE MAP TO HOSPITAL



LOCATION PLAN

BASE HOSPITAL LOCATION
TINKER AIR FORCE BASE
BIOREMEDIATION DEMONSTRATION

PNL DATE 4/6/94

APPENDIX B

LABORATORY ANALYTICAL REPORTS

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

e-mail: alpha@powernet.net
http//www.powernet.net/~alpha

2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6199
Attn: Martin Wheeler

Sampled: 01/14-29/97 Received: 01/31/97 Analyzed: 02/05-06/97

Matrix: [ ] Soil [ ] Water [X] Other

Analysis Requested: BTEX - Benzene,Toluene,Xylenes,Ethylbenzene
1,3,5-Trimethylbenzene,1,2,4-Trimethylbenzene

Methodology: EPA Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration mg/Kg	Detection Limit mg/Kg
MF-12* /BMI013197-01	Benzene	ND	530
	Toluene	ND	530
	Ethylbenzene	ND	530
	Total Xylenes	9,200	530
	1,3,5-Trimethylbenzene	4,700	530
	1,2,4-Trimethylbenzene	5,500	530
NTA-10A /BMI013197-02	Benzene	ND	48
	Toluene	ND	48
	Ethylbenzene	ND	48
	Total Xylenes	370	48
	1,3,5-Trimethylbenzene	390	48
	1,2,4-Trimethylbenzene	1,000	48

ND - Not Detected

* - The sample was received and analyzed outside of holding time.

Approved by: Roger L. Scholl Date: 2/11/97
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
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Sparks, Nevada 89431
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FAX: 702-355-0406
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(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6199
Attn: Martin Wheeler

Alpha Analytical Number: BMI013197-01

Client I.D. Number: MF-12

Date Sampled: 01/14/97

Date Received: 02/03/97

C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
<C8	GC/FID	26.18	NA	02/03/97
C9	GC/FID	16.39	NA	02/03/97
C10	GC/FID	16.86	NA	02/03/97
C11	GC/FID	12.07	NA	02/03/97
C12	GC/FID	12.26	NA	02/03/97
C13	GC/FID	8.43	NA	02/03/97
C14	GC/FID	4.87	NA	02/03/97
C15	GC/FID	1.72	NA	02/03/97
C16	GC/FID	0.60	NA	02/03/97
C17	GC/FID	0.63	NA	02/03/97

Approved by: Roger L. Scholl

Roger L. Scholl, Ph.D.
Laboratory Director

Date: 2/11/97

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(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6199
Attn: Martin Wheeler

Alpha Analytical Number: BMI013197-02

Client I.D. Number: NTA-10A

Date Sampled: 01/29/97

Date Received: 01/31/97

C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
<C8	GC/FID	0.40	NA	02/03/97
C9	GC/FID	0.85	NA	02/03/97
C10	GC/FID	2.42	NA	02/03/97
C11	GC/FID	6.16	NA	02/03/97
C12	GC/FID	11.27	NA	02/03/97
C13	GC/FID	12.47	NA	02/03/97
C14	GC/FID	14.18	NA	02/03/97
C15	GC/FID	12.05	NA	02/03/97
C16	GC/FID	10.56	NA	02/03/97
C17	GC/FID	9.19	NA	02/03/97
C18	GC/FID	7.46	NA	02/03/97
C19	GC/FID	5.29	NA	02/03/97
C20	GC/FID	3.63	NA	02/03/97
C21	GC/FID	2.24	NA	02/03/97
C22	GC/FID	1.09	NA	02/03/97
C23	GC/FID	0.43	NA	02/03/97
C24	GC/FID	0.32	NA	02/03/97

Approved by: Roger L. Scholl

Date: 2/11/97

Roger L. Scholl, Ph.D.
Laboratory Director

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No.

Proj. No.

Project Title: Biosurping

SAMPLERS: (Signature)

DATE	TIME	SAMPLE I.D.	BTEX	TPH	Trimethyl Benzene	Container No.	Number of Containers	Remarks
14 JAN 97	1630	MF-12	X	X	X		1	
29 JAN 97	0840	NTA-10A	X	X	X		1	

Relinquished by: (Signature)	Date/Time		Received by: (Signature)	Relinquished by: (Signature)	Date/Time		Received by: (Signature)
	30 JAN 97	0715					

Relinquished by: (Signature)	Date/Time		Received by: (Signature)	Relinquished by: (Signature)	Date/Time		Received by: (Signature)

Relinquished by: (Signature)	Date/Time		Received for Laboratory by: (Signature)	Date/Time		Remarks
				1/31/97	1200	

Page of

Billing Information:

Name

Address

City, State, Zip

Phone Number ______ Fax ______

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Page # 1 of 1

Client Name: Kathill	P.O. #	Job #
Address	PWS #	DWR #
City, State, Zip	Phone #	Fax #

Sampled by: Client

Report Attention: Martin Wheeler

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	TPH	BTXE	Trimethyl Benzene						REMARKS
1630	1/14	OT	BMI 013197-01	MF-12	1-O	x	x	x						
0840	1/29	✓	02	NTA-10A	1-O	x	x	x						

SPECIAL INSTRUCTIONS:

product

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	[illegible]	Linda Bydaick	AAI	1/31/97	1200
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other **: L-Liter V-Voa S-Soil Jar O-Orbo T-Tedlar B-Brass P-Plastic OT-Other

Alpha Analytical, Inc.
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1-800-283-1183

e-mail: alpha@powernet.net
http//www.powernet.net/~alpha

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Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6199
Attn: Martin Wheeler

Sampled: 01/29/97   Received: 01/31/97   Analyzed: 02/05/97

Matrix: [ ] Soil   [X] Water   [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline
BTEX - Benzene,Toluene,Ethylbenzene,Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
Tinker-NTA-10A-1 /BMI013197-03	TPH (Purgeable)	53	25	mg/L
	Benzene	ND	50	ug/L
	Toluene	82	50	ug/L
	Ethylbenzene	180	50	ug/L
	Total Xylenes	490	50	ug/L

ND - Not Detected

Approved by: Roger L. Scholl   Date: 2/6/97
Roger L. Scholl, Ph.D.
Laboratory Director

Billing Information:

Name
Address
City, State, Zip
Phone Number Fax

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Client Name Battelle	P.O. #	Job #	
Address	PWS #	DWR #	
City, State, Zip	Phone #	Fax #	

Sampled by Client

Report Attention Martin Wheeler

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	BTXE	TPHg						REMARKS
	1/29	AQ	BMI013197-03	TINKER-NTA-10A-1	3V	x	x						

SPECIAL INSTRUCTIONS:

Jet fuel per Al Pollack 2/3/97

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	Linda Bydairk	Linda Bydairk	AAI	1/31/97	1200
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other **: L-Liter V-Voa S-Soil Jar O-Orbo T-Tedlar B-Brass P-Plastic OT-Other

REVISED

Laboratory
Analysis Report

Sierra
Environmental
Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 3/03/97
Client : ALP-855
Taken by: CLIENT
Report : 18697
PO# :

ample	Collected Date	Time	PARTICLE SIZE CLASSIF. HYDROMETER	DENSITY G/CM3	POROSITY			
BMI012797-03 - T2-MPA-7.5-8	1/20/97	:	SEE REPORT	1.27	52.1			
BMI012797-05 - T2-MPC-5-5.5	1/20/97	:	SEE REPORT	1.13	57.4			

Approved By:

William F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager

Billing Information:

Name

Address

City, State, Zip

Phone Number Fax

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Client Name Battelle	P.O. #	Job #	
Address	PWS #	DWR #	
City, State, Zip	Phone #	Fax #	

Sampled by Client

Report Attention Al Pollack

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	TPHg	BTXE	ASTM D422	Bulk Density	Porosity	TPH				REMARKS
	1/18	AQ	BMI012797-01	TINKER-MF-12-1	3V	X	X								
	1/20	✓	02	TINKER-MF-12-2	2V	X	X								1 VOA Rec'd broken
		SO	03	T2-MPA-7.5-8	1B			X	X	X					
		✓	04	T2-MPA-7.7.5	1B		X				X				
		✓	05	T2-MPC-5-5.5	1B			X	X	X					
		✓	06	T2-MPC-6.25-6.75	1B		X				X				

SPECIAL INSTRUCTIONS:

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	Linda Bijdairk	Linda Bijdairk	AAI	1/27/97	1030
Relinquished by					
Received by					
Relinquished by					
Received by					

[redacted] NOTE: Samples are discarded 60 days after results [redacted] report[redacted] less o[redacted] rang[redacted] s are[redacted]. Ha[redacted] s sa[redacted] will b[redacted] ned t[redacted] t or d[redacted] d of [redacted] t ex[redacted]

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other ** L-Liter V-Voa S-Soil Jar O-Orbo T-Tedlar B-Brass P-Plastic OT-Other

Sierra
Environmental
Monitoring, Inc.

February 6, 1997

TO: **Alpha Analytical**

FROM: Sierra Environmental Monitoring, Inc.

RE: Particle Size Distribution Analysis for Samples:

SEM 9701-0669	BMI 012797-03-T2-MPA-7.5-8
SEM 9701-0670	BMI 012797-05-T2-MPA-5-5.5

As per your request, we have performed particle size analysis on the samples submitted to our laboratory. Test results are as follows:

9701-0669	**Clay: 22.0 %**	**Silt: 29.0 %**	**Sand: 49.0 %**
9701-0670	**Clay: 9.5 %**	**Silt: 10.3 %**	**Sand: 80.2 %**

The samples were passed through a #10 sieve prior to analysis as per procedure. All results are based on oven dry sample weights.

We appreciate this opportunity to provide our laboratory testing services. If you have any questions or require further testing, please feel free to contact us at your convenience.

Sincerely,
SIERRA ENVIRONMENTAL MONITORING, INC.

John Seher
Laboratory Manager

William F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
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Las Vegas, Nevada
(702) 498-3312
FAX: (702) 736-7523
Sacramento, California
(916) 366-9089
FAX: (916) 366-9138

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 01/20/97 Received: 01/27/97 Analyzed: 01/29-31/97

Matrix: [X] Soil [ ] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Extractable Quantitated As Diesel
BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - EPA Method 624/8240

TPH/BTXE Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
T2-MPA-7-7.5 /BMI012797-04	TPH *	190	10	mg/Kg
	Benzene	ND	20	ug/Kg
	Toluene	ND	20	ug/Kg
	Ethylbenzene	ND	20	ug/Kg
	Total Xylenes	ND	20	ug/Kg
T2-MPC-6.25-6.75 /BMI012797-06	TPH	ND	10	mg/Kg
	Benzene	ND	20	ug/Kg
	Toluene	ND	20	ug/Kg
	Ethylbenzene	ND	20	ug/Kg
	Total Xylenes	ND	20	ug/Kg

* - Components are in the range of jet fuel.

ND - Not Detected

Approved By: Roger L. Scholl Date: 2/4/97
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
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Sparks, Nevada 89431
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e-mail: alpha@powernet.net
http//www.powernet.net/~alpha

Las Vegas, Nevada
(702) 498-3312
FAX: (702) 736-7523
Sacramento, California
(916) 366-9089
FAX: (916) 366-9138

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#:
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 01/18-20/97 Received: 01/27/97 Analyzed: 01/29/97

Matrix: [ ] Soil [X] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable
Quantitated As Gasoline
BTEX - Benzene, Toluene, Ethylbenzene, Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
Tinker-MF-12-1 /BMI012797-01	TPH (Purgeable)	23	5.0	mg/L
	Benzene	1,400	10	ug/L
	Toluene	890	10	ug/L
	Ethylbenzene	610	10	ug/L
	Total Xylenes	2,900	10	ug/L
Tinker-MF-12-2 /BMI012797-02	TPH (Purgeable)	27	5.0	mg/L
	Benzene	2,100	10	ug/L
	Toluene	480	10	ug/L
	Ethylbenzene	580	10	ug/L
	Total Xylenes	2,700	10	ug/L

Approved by: Roger L. Scholl Date: 2/4/97
Roger L. Scholl, Ph.D.
Laboratory Director

Battelle

CHAIN OF CUSTODY

Company Contact: AL Pollack Telephone: 614-424-3753

Samples Collected by: MARTIN WHEELER / Greg Headington Date: 18/20 JAN 97 Time: 1200/1353

Sample Location: TINKER AFB, 290 FUEL YARD

Ice Chest No.: Field Logbook Page No.:

Remarks:

Method of Shipment: FEDEX

Sample Identification

TINKER-MF-12-1 3 VIALS	TPH-GAS / BTEX 8015 / 8240
TINKER MF-12-2 3 VIALS	TPH-GAS / BTEX 8015 / 8240
T2-MPA-7.5-8	ASTM D422 / BULK DENSITY / POROSITY /
T2-MPA-7-7.5	BTEX, TPH
T2-MPC-5-5.5	ASTM D422 / BULK DENSITY / POROSITY
T2-MPC-6.25-6.75	BTEX, TPH

Chain of Possession

Relinquished by:	Received by:	Date/Time:
[signature]	[signature]	1/27/97 1020
Relinquished by:	Received by:	Date/Time:
Relinquished by:	Received by:	Date/Time:
Relinquished by:	Received by:	Date/Time:

Billing Information:

Name
Address
City, State, Zip
Phone Number Fax

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Client Name Battelle
Address
City, State, Zip

P.O. #
PWS #
Phone #

Job #
DWR #
Fax #

Sampled by Client
Report Attention Al Pollack

Analyses Required

Time Sampled	Date Sampled	Matrix* See Key Below	Office Use Only Lab ID Number	Sample Description	Total and type of containers ** See below	TPH/g	BTXE	ASTM D422	Bulk Density	Porosity	TPH			REMARKS
	1/18	AQ	BMI012797-01	Tinker-MF-12-1	3V	X	X							
	1/20	✓	02	Tinker-MF-12-2	2V	X	X							1 VOA rec'd broken
		SO	03	T2-MPA-7.5-8	1B			X	X	X				
		✓	04	T2-MPA-7.7.5	1B		X				X			
		✓	05	T2-MPC-5-5.5	1B			X	X	X				
		✓	06	T2-MPC-6.25-6.75	1B		X				X			

SPECIAL INSTRUCTIONS:

	Signature	Print Name	Company	Date	Time
Relinquished by	[signature]	Linda Budnick	AAI	1/27/97	1030
Received by	[signature]	Craig Giesy	AAI	1/27/97	14:50
Relinquished by					
Received by	[signature]		Sav	1-27-97	1450
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

[redacted] Key: [redacted] Aqueous [redacted] S[redacted] Soil [redacted] WA - Waste [redacted] OT - Other [redacted] ** L-Liter [redacted] V-Voa [redacted] S-Soil Jar [redacted] O-Orbo [redacted] T-Tedlar B-Brass P-Plastic [redacted] OT-Other

Laboratory Analysis Report

Sierra
Environmental
Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 2/07/97
Client : ALP-855
Taken by: CLIENT
Report : 18697
PO# :

Sample	Collected Date	Time	ALKALINITY, TOTAL MG/L CACO3	PARTICLE SIZE CLASSIF. HYDROMETER	DENSITY G/CM3	POROSITY		
BMI012797-03 - T2-MPA-7.5-8	1/20/97	:	52.1	SEE REPORT	1.27			
BMI012797-05 - T2-MPC-5-5.5	1/20/97	:		SEE REPORT	1.13	57.4		

New report w/ this correction
Should be coming ' 3-2-97
L.S.

702-857-2400

Approved By:

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

William F. Pillsbury
President

John C. Seher
Manager

@ AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 9701261

Work Order Summary

CLIENT: Ms. Amanda Bush
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201-2693

BILL TO: Same

PHONE: 614-424-4996
FAX: 614-424-3667
DATE RECEIVED: 1/31/97
DATE COMPLETED: 2/5/97

INVOICE # 13219
P.O. # 91221
PROJECT # G462201 Bioslurping Tinker AFB

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.
01A	Tinker-MF-12-1	TO-3	1.5 "Hg
02A	Tinker-MF-12-2	TO-3	1.5 "Hg
03A	Tinker-NTA-10A-1	TO-3	0 "Hg
04A	Lab Blank	TO-3	NA

CERTIFIED BY: Robert Dooma
Laboratory Director

DATE: 2/5/97

AIR TOXICS LTD.

SAMPLE NAME: Tinker-MF-12-1

ID#: 9701261-01A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6013108		Date of Collection: 1/18/97	
Dil. Factor:	5325		Date of Analysis: 1/31/97	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	5.3	17	270	880
Toluene	5.3	20	140 M	540 M
Ethyl Benzene	5.3	24	96	420
Total Xylenes	5.3	24	300	1300

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6013108		Date of Collection: 1/18/97	
Dil. Factor:	5325		Date of Analysis: 1/31/97	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	53	350	66000	430000
C2 - C4** Hydrocarbons	53	97	6000	11000

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

M = Reported value may be biased due to apparent matrix interferences.

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Tinker-MF-12-2

ID#: 9701261-02A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6013109		Date of Collection: 1/20/97	
Dil. Factor:	5325		Date of Analysis: 1/31/97	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	5.3	17	220	710
Toluene	5.3	20	Not Detected	Not Detected
Ethyl Benzene	5.3	24	100	440
Total Xylenes	5.3	24	280	1200

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6013109		Date of Collection: 1/20/97	
Dil. Factor:	5325		Date of Analysis: 1/31/97	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	53	350	69000	450000
C2 - C4** Hydrocarbons	53	97	2400	4400

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Tinker-NTA-10A-1

ID#: 9701261-03A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6013110		Date of Collection: 1/29/97	
Dil. Factor:	337		Date of Analysis: 1/31/97	
Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.34	1.1	8.2	27
Toluene	0.34	1.3	14	54
Ethyl Benzene	0.34	1.5	22	97
Total Xylenes	0.34	1.5	54	240

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6013110		Date of Collection: 1/29/97	
Dil. Factor:	337		Date of Analysis: 1/31/97	
Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	3.4	22	3700	24000
C2 - C4** Hydrocarbons	3.4	6.2	150	270

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank
ID#: 9701261-04A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6013106		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 1/31/97	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	0.001	0.003	Not Detected	Not Detected
Toluene	0.001	0.004	Not Detected	Not Detected
Ethyl Benzene	0.001	0.004	Not Detected	Not Detected
Total Xylenes	0.001	0.004	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name:	6013106		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 1/31/97	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	0.010	0.065	Not Detected	Not Detected
C2 - C4** Hydrocarbons	0.010	0.018	Not Detected	Not Detected

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA

AIR TOXICS LTD.
AN ENVIRONMENTAL ANALYTICAL LABORATORY

180 BLUE RAVINE ROAD, SUITE B
FOLSOM, CA 95630-4719
(916) 985-1000 FAX: (916) 985-1020

CHAIN-OF-CUSTODY RECORD

Nº 009797

Page ___ of ___

Contact Person AL POLLACK
Company BATTELLE
Address 505 King AVE City Columbus State OH Zip 43201
Phone 614-424-3753 FAX 614-424-3667
Collected By: Signature [signature]

Project info:
P.O. # ___
Project # ___
Project Name Bioslurping

Turn Around Time:
☒ Normal
☐ Rush ___ Specify

Lab I.D.	Field Sample I.D.	Date & Time	Analyses Requested	Canister Pressure / Vacuum Initial	Final	Receipt
01A	TINKER-MF-12-1	18 JAN 97 1240	BTEX, TPH	23.5 "Hg	0 "Hg	1.5" Hg
02A	TINKER-MF-12-2	20 JAN 97 1312	BTEX, TPH	26" Hg	0 " Hg	1.5" Hg
03A	TINKER-NTA-10A-1	29 JAN 97 0915	BTEX, TPH	26" Hg	0 "Hg	0" Hg

Relinquished By: (Signature) [signature] Date/Time 30 JAN 97 0715 Print Name MARTIN WHEELER
Relinquished By: (Signature) Date/Time Received By: (Signature) Date/Time
Relinquished By: (Signature) Date/Time Received By: (Signature) Scott Amerson ATL Date/Time 1/31/97 1012

Notes: SENDING BACK 5 CANISTERS - DID NOT USE CANISTER NUMBERS 949 + 747

Lab Use Only	Shipper Name	Air Bill #	Opened By:	Date/Time	Temp. (°C)	Condition	Custody Seals Intact?	Work Order #
	FED EX	3608887855	[signature]	1/31/97 1012	AMBIENT	GOOD	Yes No (None) N/A	9701201

APPENDIX C

SYSTEM CHECKLIST

Checklist for System Shakedown

Site: Tinker AFB

Date: 1.13.97

Operator's Initials: MW + GH

Equipment	Check if OK	Comments
Liquid Ring Pump	✓	
Aqueous Effluent Transfer Pump	✓	
Oil/Water Separator	✓	
Vapor Flow Meter	✓	
Fuel Flow Meter	✓	
Water Flow Meter	✓	
Emergency Shut Off float Switch Effluent Transfer Tank	✓	
Analytical Field Instrumentation GasTechtor O_2/CO_2 Analyzer TraceTechtor Hydrocarbon Analyzer Oil/Water Interface Probe Magnehelic Boards Thermocouple Thermometer	 ✓ ✓ ✓ ✓ ✓	

APPENDIX D

DATA SHEETS FROM THE SHORT-TERM PILOT TEST

WELL	MF-12	DATE 5 JAN 96	
TIME	DEPTH TO PRODUCT	DEPTH TO WATER	PRODUCT LAYER
0	11.85	12.93	1.08
1		1390	
2		13.05	
3		12.70	
4		12.42	
5	12.18	12.19	.01
10	12.06	12.08	.02
15	11.94	11.97	.03
30	11.85	11.93	.08
1hr	11.79	11.90	.11
1.5hr	11.76	11.87	.11
2	11.72	12.12	.40
2.5	11.69	12.29	.60

FUEL AND WATER RECOVERY DATA

Site: 290 Fuel yd/Tinker

Start Date: 16 JAN 97 1153

Test Type: Slurping

Operators: Leeson/Headington/Wheeler

Date/Time	Time	LNAPL Recovery	Groundwater Recovery
17 JAN 97 0800	0800 20.4	Have Recovered Fuel	677.5 gals
17 JAN 97 1730	1730 29.6	—	1029 gals.
18 JAN 97 0830	0830 44.6	10 gals Pumped + 5 in Ertl Tank	1381
19 JAN 97	0800 68.1	8.3 + 3 in System	1993
20 JAN 97	810 92.3	7.8	2695

PILOT TEST PUMPING DATA

Site: 290 FUEL YARD/TINKER

Start Date: 16 JAN 97

Operators: LEESON, HEADINGTON, WHEELER.

Start Time: 1153

Test Type: Slurping

Well ID: MF-12

Depth to Groundwater: 12.725

Depth to Fuel: 12.72

Depth of Tube: 12.92

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in H_2O)	Vapor Extraction: Carbon Drums (in H_2O)	Vapor Extraction: Flowrate (scfm)	Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
17 JAN 0800	20 Hrs	TOO LOW TO MEASURE		TOO LOW TO MEASURE	24.9	25	
17 JAN 1730	29.5	" "		" "	33.4	25	
18 JAN 0830	44.5	" "		" "	30.8	25	
19 JAN 0800	68	" "		" "	38.4	24	
20 JAN 0810	92	" "		" "	34.0	24	

PILOT TEST PUMPING DATA

Site: 290 Fuel yp/Tinker

Start Date: 20 JAN 97

Operators: LEESON, HEADINGTON, WHEELER

Start Time: 0855

Test Type: Skimming

Well ID: MF-12

Depth to Groundwater: ______

Depth to Fuel: ______

Depth of Tube: 12.92

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
		Stack Pressure (in H_2O)	Carbon Drums (in H_2O)	Flowrate (scfm)			
20JAN 0855	0	.09		33.7		17	

PILOT TEST PUMPING DATA

Site: 290 Fuel YD/TINKER

Start Date: 21 JAN 97

Operators: LEESON/HEADINGTON/WHEELER

Start Time: 0927

Test Type: DRAWDOWN.

Well ID: MF-12

Depth to Groundwater: ______ Depth to Fuel: ______ Depth of Tube: 16'

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in H_2O)	Vapor Extraction: Carbon Drums (in H_2O)	Vapor Extraction: Flowrate (scfm)	Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
21 JAN 0927	0	.01		~~34~~ 15		20"	

WELL	EC-5	DATE 2JAN96	
TIME	DEPTH TO PRODUCT	DEPTH TO WATER	PRODUCT LAYER
0	17.73	17.83	.1
1	—	19.72	—
2	—	19.61	—
3	—	19.51	—
4	—	19.43	—
5	19.33	19.35	.02
10	19.13	19.19	.06
15	18.95	19.05	.1
30	18.87	18.97	.1
45	18.78	18.90	.12
1 hr	18.73	18.85	.12
3JAN96 ~18hr	17.73	17.80	.07
~24 hr	17.73	17.82	.09

WELL	NTA 14A	DATE 2JAN97	
TIME	DEPTH TO PRODUCT	DEPTH TO WATER	PRODUCT LAYER
0	19.75	20.39	.64
1 min	21.52	21.69	.17
2 min	21.39	21.55	.16
3 min	21.28	21.45	.17
4 min	21.19	21.38	.19
5 min	21.13	21.30	.17
10 min	20.95	21.13	.18
15 min	20.57	20.75	.18
30 min	20.47	20.65	.18
1 hr	20.40	20.59	.19
3JAN96 1BW	19.85	20.04	.19
~ 24 hr	19.83	20.04	.21

PILOT TEST PUMPING DATA

Site: NORTH TANK/TINKER

Start Date: 23 JAN97

Operators: HEADINGTON/WHEELER

Start Time: 1100

Test Type: Skimming

Well ID: NTA-104

Depth to Groundwater: NO H_2O ~~DETECTED~~ AFT. START UP 25.6

Depth to Fuel: 19.57-32.35

Depth of Tube: 25.3 ADJ. TO 25.5

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
		Stack Pressure (in H_2O)	Carbon Drums (in H_2O)	Flowrate (scfm)			
23 JAN 1100	1.3 hrs	.14 / .21		42 / 51	45.0	10	
24 JAN 0842	21.42	.23		54	44.8	9	
25 JAN 0914	24.72	.24		54.5	41.7	7	

PILOT TEST PUMPING DATA

Site: NORTH TANK/TINKER

Start Date: 25 JAN 97

Operators: HEADINGton/WHEELER

Start Time: 1120

Test Type: Slurping

Well ID: NTA-10A

Depth to Groundwater: 24.36

Depth to Fuel: ______

Depth of Tube: 24.9

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
		Stack Pressure (in H_2O)	Carbon Drums (in H_2O)	Flowrate (scfm)			
25 JAN 1120	0	.01		15	34.1	23	
27 JAN 1100	~~24~~ 0	.01		15		24	
28 JAN 0740	20.4	TOO LOW TO MEASURE		TOO LOW TO MEASURE	35.5	24	
29 JAN 0800	24.4	"		"	35.7	24	
30 JAN 0817	24	"		"		24	
	77 hrs						
	time						

PILOT TEST PUMPING DATA

Site: NORTH TANK/TINKER

Start Date: 30 JAN 97

Operators: HEADINGTON/WHEELER

Start Time: 1247

Test Type: SKIMMING

Well ID: NTA-10A

Depth to Groundwater: ______

Depth to Fuel: ______

Depth of Tube: 25.5

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in H_2O)	Vapor Extraction: Carbon Drums (in H_2O)	Vapor Extraction: Flowrate (scfm)	Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
30JAN 1247	0	.23		54		9	
31JAN 0820	19.73	.21		51	42.9	9	

PILOT TEST PUMPING DATA

Site: NORTH TANK/TINKER

Start Date: 31 JAN 97

Operators: HEADINGTON/WHEELER

Start Time: 1305

Test Type: DRAWDOWN

Well ID: NTA-10A

Depth to Groundwater: ______

Depth to Fuel: ______

Depth of Tube: 27' AND 28'

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
		Stack Pressure (in H_2O)	Carbon Drums (in H_2O)	Flowrate (scfm)			
31 JAN 97 1305	0	.13		35	42.7	12	
1 FEB 97 1119	22.12	.155		42	43.9	10	
2 FEB 97 0910	44.12	.155		42	43.6	9	

FUEL AND WATER RECOVERY DATA

Site: NORTH TANK/TINKER

Start Date: 23 JAN 97 10:50

Test Type: SKIMMING

Operators: HEADINGTON/WHEELER

Date/Time	Time	LNAPL Recovery	Groundwater Recovery
24 JAN 97	0842 21.9	18 + 5 in system	220 gals
25 JAN 97	0914 46.4	15 gals	165
	1058 48.1	stopped 7	15
Total		45	400

FUEL AND WATER RECOVERY DATA

Site: NORTH TANK/TINKER

Start Date: 25 JAN 97 1120

Test Type: Slurping

Operators: Headington/WHEELER

Date/Time	Time	LNAPL Recovery	Groundwater Recovery
28 JAN 97	0740 74.1	30 gals + 40	2280 gals
29 JAN 97	0801 ~~[illegible]~~	47.5 30 gals + 40	2315 gals
30 JAN 97	0817 71.7	30 gals	2200 gals
	1042 74.1		
		~~160~~ 170 gals total –	
		During Slurping.	
25 Jan 97	1337	Generator quit	
	1457	restarted	
	1551	Shutdown	
27 Jan	1100	Restart	

FUEL AND WATER RECOVERY DATA

Site: NORTH TANK/TINKER

Start Date: 30 JAN 97 1247

Test Type: SKIMMING

Operators: HEADINGTON/WHEELER

Date/Time	Time	LNAPL Recovery	Groundwater Recovery
31 JAN 97	~~0830~~ 1145 23	10 gals	800 gals

FUEL AND WATER RECOVERY DATA

Site: NORTH TANK

Start Date: 31 JAN 97 1305

Test Type: DRAWDOWN

Operators: Headington/Wheeler

Date/Time	Time	LNAPL Recovery	Groundwater Recovery
1 FEB 97	1117 22.2	40 gals	1398.0 gals
2 FEB 97	0910 44.1	20 gals	656.2 gals
	1040 45.6	Shutdown	

APPENDIX E

SOIL GAS PERMEABILITY TEST RESULTS

12:56:55

Record Sheet for Air Permeability Test

Site: [illegible]	Monitoring Point: 17A
Liquid ring pump size: 7.5 hp	Distance from recovery well: 17 ft
Depth of points: Green = 3	Recorded by: [illegible]
Blue = 5	F > 22.5 ft
Red = 8	C - 37.5 ft

Time	Green	Blue	Red	Time	Green	Blue	Red
0	0	0.0040	-0.0025				
1	0	0.0040	0.0025				
3	0	0.0040	0.0025				
5	0	0.0040	0.0058				
10	0	0	0				
30	0	0	0				
143	0	0	0				

Remarks:

Record Sheet for Air Permeability Test

Site: Tinker AFB, 290 POL Fuel [illegible]	Monitoring Point: MP B
Liquid ring pump size: 7.5	Distance from recovery well: 22.5 FT
Depth of points: Green = 3	Recorded by: M. Wheeler
Blue = 5	
Red = 7	

Time	Green	Blue	Red	Time	Green	Blue	Red
1 min	.01	.01	.02				
3 min	.015	.02	.02				
5 min	.02	.02	.02				
10 MIN	.02	.02	.02				
30 min	.02	.02	.02				
143 MIN	.02	.02	.03				

Remarks:

Record Sheet for Air Permeability Test

Start 1153 HR

Site: Tinker AFB / Area 290	Monitoring Point: C
Liquid ring pump size: 7 1/2 HP	Distance from recovery well: 37.5'
Depth of points: Green = 3.0'	Recorded by: Healy
Blue = 5.0'	Slurping (tube depth 12.92')
Red = 7.0'	MW - MF - 12

Time	Green	Blue	Red	Time	Green	Blue	Red	
0	0.0"	0.0"	0.0"					
1 min	0.0"	0.0"	0.0"					
9 min	0.0"	0.0"	0.0"					
140 min	0.0	0.0	0.0					
					PUMP			
		WATER TOTALIZER	STACK TEMP	Water TEMP	PUMP VAC	WELL VAC	Stack flow	
				Start 40.7°C	25" Hg	20" Hg	Flow	FROZEN
				37°C	26" Hg	20" Hg		10 min
				38°C	26" Hg	20" Hg	0.01" DP	140 min
		91 Gallons	26.9°C	"	"	"	0.0	145 min
						Hour meter		
		101.5				253.5	1423 HR	150 min
		Measured water	rate	6 liter	/112 sec			
				6000 cc /	112 sec			
				53.6 cc/sec				
				3214 cc/min				
				0.85 GPM				
	STACK temp	Water Meter	Seal TANK TEMP	Well VAC	PUMP VAC	HR Meter		
	25.8°	197.5 GAL	36.7°	20" Hg	26" Hg	256 HRS	NO FLOW	
		Collection Fuel		but can't determine volume				
1715 HRS	temp = 20°F		BP = 29.24" Hg		RH = 46%			

Remarks: Water meter start 2.2 gallons
Note: the Filter tank had to fill
with water so meter readings are off.

APPENDIX F

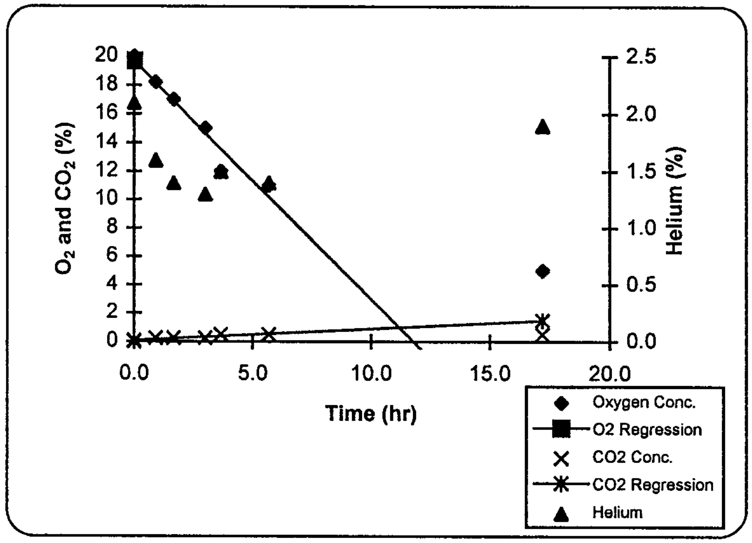
IN SITU RESPIRATION TEST RESULTS

In Situ Respiration Test: Data Analysis

Date: 1/21/97 **Site Name:** Tinker Area 290

Monitoring Point: MPA **Depth of MP (ft):** 5'

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
1/21/97 13:40	0.0	20.00	0.00	2.10
1/21/97 14:34	0.9	18.20	0.25	1.60
1/21/97 15:20	1.7	17.00	0.25	1.40
1/21/97 16:40	3.0	15.00	0.25	1.30
1/21/97 17:20	3.7	12.00	0.50	1.50
1/21/97 19:21	5.7	11.00	0.50	1.40
1/22/97 6:52	17.2	5.00	0.50	1.90



Biodegradation Rate (mg/kg/day)

27.598

O_2 Utilization Rate

Ko	
0.028	%/min
1.670	%/hr
40.070	%/day

Regression Lines	O_2	CO_2
Slope	-1.6696	0.0808
Intercept	19.6841	0.0909
Determination Coef.	0.9472	0.7826
No. of Data Points	6	6

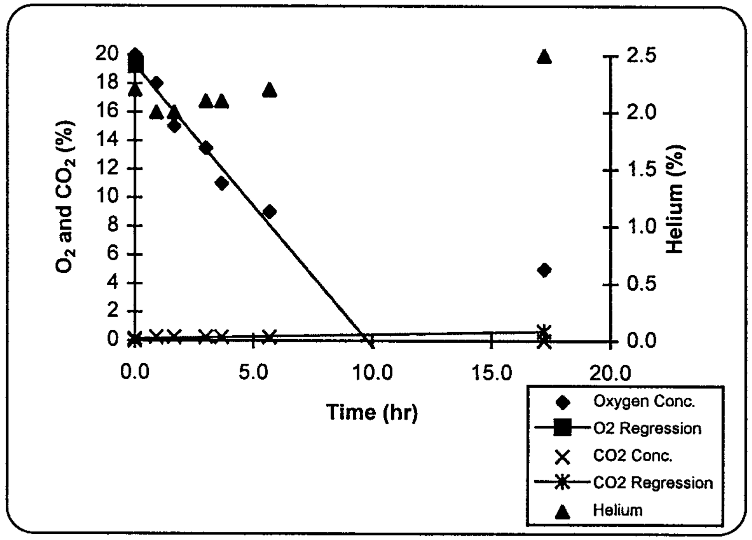
(2)

In Situ Respiration Test: Data Analysis

Date: 1/21/97 **Site Name:** Tinker Area 290

Monitoring Point: MPB **Depth of MP (ft):** 7'

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
1/21/97 13:40	0.0	20.00	0.00	2.20
1/21/97 14:34	0.9	18.00	0.25	2.00
1/21/97 15:20	1.7	15.00	0.25	2.00
1/21/97 16:40	3.0	13.50	0.25	2.10
1/21/97 17:20	3.7	11.00	0.25	2.10
1/21/97 19:21	5.7	9.00	0.25	2.20
1/22/97 6:52	17.2	5.00	0.00	2.50



Biodegradation Rate (mg/kg/day)

32.569

O_2 Utilization Rate

Ko
0.033 %/min
1.970 %/hr
47.288 %/day

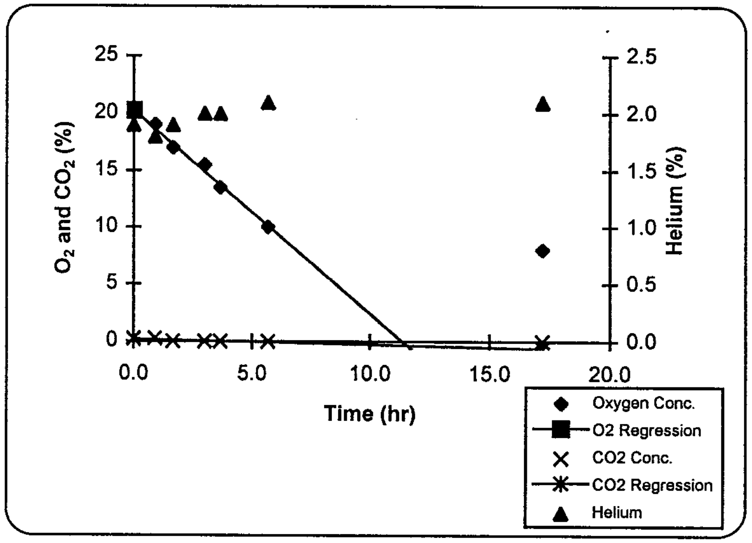
Regression Lines	O_2	CO_2
Slope	-1.9703	0.0293
Intercept	19.3151	0.1356
Determination Coef.	0.9568	0.3491
No. of Data Points	6	6

In Situ Respiration Test: Data Analysis

Date: 1/21/97 **Site Name:** Tinker Area 290

Monitoring Point: MPC **Depth of MP (ft):** 8'

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
1/21/97 13:40	0.0	20.00	0.25	1.90
1/21/97 14:34	0.9	19.00	0.25	1.80
1/21/97 15:20	1.7	17.00	0.00	1.90
1/21/97 16:40	3.0	15.50	0.00	2.00
1/21/97 17:20	3.7	13.50	0.00	2.00
1/21/97 19:21	5.7	10.00	0.00	2.10
1/22/97 6:52	17.2	8.00	0.00	2.10



Biodegradation Rate (mg/kg/day)

29.495

O_2 Utilization Rate

Ko 0.030 %/min
1.784 %/hr
42.824 %/day

Regression Lines	O_2	CO_2
Slope	-1.7844	-0.0479
Intercept	20.2694	0.2025
Determination Coef.	0.9900	0.5853
No. of Data Points	6	6

(2)